Ingredients for Improving the Culture of STEM Degree Attainment with Co-Curricular Supports for Underrepresented Minority Students

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Closing the gap

For over 40 years, hundreds of undergraduate co-curricular intervention and training programs in the U.S. have been used to increase interest and persistence in STEM fields. Many private and publically funded programs have focused specifically on increasing the number of underrepresented minorities (URMs) and women because members of these groups‘ often fail to gain interest or persist in STEM fields once they enter. However, the effectiveness of these programs, particularly regarding biomedical and science fields, has been criticized (Collea, 1990; Harrell & Forney, 2003; Mervis, 2006). Meanwhile the graduation rates for URM STEM students, while higher than 30 years ago, are still far from being representative of the percentage of URMs in the U.S. population and the effects of low income fail to explain the persistence of these inequalities (Gerald & Haycock, 2006).

John Bailar, emeritus University of Chicago statistician and part of the National Academies' National Research Council (NRC) Board on Higher Education and Workforce who assessed the NIH Minority Research and Training Programs in 2005 stated, "We were asked to find out what works, and we couldn't do it because of serious problems with the data" (Mervis, 2006). In a rather critical review of this report, Mervis (2006) described some of the reasons the report lacked "good data," which included low coordination among individual programs, non-random participation of students in organized studies (with a response rate of only 13.7% in the NRC study), and director reports that do not include longitudinal information regarding participants long-term career choices. In short, the report strongly emphasized the necessity of stronger design and data to measure program outcomes.

Call for Better Research

The National Advisory Council of the NIGMS (January, 2006) called internally for better documentation of outcome and evaluations of the success of individual programs, which are intended to increase interest, motivation, and preparedness of URM students for careers in biomedical research. A NIGMS- Division of Training, Workforce Development and Diversity (TWD; formerly the Division of Minority Opportunities in Research) white paper further articulated that programs could be improved with prescriptive and mandated program requirements, but that insufficient evidence existed on what those prescriptions and mandated elements should be. Meanwhile, the leadership at NIGMS-TWD recognized the need for valid data testing the effectiveness and underlying assumptions of intervention programs. In 2003, an initiative was launched, now re-named *Research to Understand and Inform Interventions that Promote the Research Careers of Students in Biomedical and Behavioral Sciences*. This paper seeks to report upon findings from this initiative, in addition to other relevant research, that have emerged over the past nine years regarding undergraduate co-curricular activities, with special attention paid to the impacts on URM populations seeking careers in STEM fields. In addition, studies of co-curricular program components will be described, although random assignment to isolated program components to assess impacts still remains rare. In some cases, the term, "emergent research" will be used to denote current research being conducted from which findings are still outstanding. Some additional literature, relevant to improving co-curricular culture, also is provided to enhance the breadth of this white paper.

Defining "Improvement"

To identify the ingredients for "improving" co-curricular activities, the discussion must begin with defining what constitutes improvement. Review of the 31 NIH funded studies designed to assess the efficacy of co-curricular URM science programs, showed that the most common metric of successful interventions is documenting an increase in students' interests and persistences such that students are more likely to *major in a STEM field*, *graduate with a STEM degree*, *enroll in STEM courses, apply to graduate school including masters, doctoral, and medical programs, work in a STEM field, have peer reviewed publications, and eventually serve as a principle investigator on RO1 grants*. In short, across a variety of studies, the common feature of "improvement" or success is that students *do* something as a consequence of their involvement in co-curricular program that results in continued involvement and accomplishments in STEM fields. Shorter-term metrics of successful programs includes student acquisition of skills, increased motivation, and intention to pursue a research career.

While hard behaviors are the "gold standard" of measuring improvement, for many researchers self-reported intention is actually what is measured. From the field of social psychology, there is strong evidence that the leap from intention to actual engagement is not far (Kaiser & Wilson, 2004), especially when the intention is specific.[1] Further, Lent and others have found that intention to pursue STEM majors does predict enrollment and persistence behaviors (Lapan, Shaughnessy, and Boggs, 1996; Lent, Brown, Nota, & Salvatore, 2003) as well as science related performance (Luzzo, Hasper, Albert, Biby, & Martinelli, 1999; Sullivan & Mahalik, 2000). Thus, research indicates that there is reason to acquire intention information as an interim measure for behavioral outcomes or as a predictor.

In addition to student STEM career engagement, some recognized metrics of successful co-curricular programs include a) sustainability (meaning that the program is sustainable across years); b) potential for program to be scaled-up, or applied in other institutions/settings; c) cost effectiveness, and d) replicated demonstration that the co-curricular program achieves pre-

[1] For more information on this, please see the theory of planned behavior research, which links intentions to behaviors in Armitage & Conner, 2001; Cooke & French,2008; Ajzen & Fishbein, 1980.

determined outcomes (defined by the objectives of the program compared to a control or comparison groups). Programs with these features are seen as having the capacity to contribute to longer-term improvements since they have the capacity to be sustained and shared.

Co-curricular Support Program Activities and Assessment

Co-curricular support programs and activities provide undergraduates with a variety of experiences. Some of the most common features of these programs include the following: Financial support, research experience, internships, mentorship, and academic tutoring. More recently, program activities have sometimes included multi-media activities such as developing online videos regarding STEM interests.

The majority of the evaluations of these programs have been empirically limited. First, most assessments included comparing the percentage of students who persisted in or maintained interest in STEM careers with students from the same institution who did not participate in the program. This comparison of non-randomized groups does not account for selection biases that can occur. The outcomes may, ultimately reflect excellent ability to select students who are likely to persist (even without the program) than those who are not selected. Without randomized selection or providing a relatively equal comparison group (such as a propensity score matched group), program impacts are not entirely clear. Second, sometimes program participants are contacted after they completed the program and were asked to reflect on how the program helped them. In several of these sorts of studies, the evaluators were not able to contact all previous attendees. Thus, a subgroup of students (sometimes as low as 25 or 30%), who perhaps were more likely to stay in touch with program staff, constituted a potentially biased sub-sample of program attendees. Retrospective studies with high response rates or prospective studies, that capture student experiences as they occur for all or most attendees, provide a stronger design for assessing program component impacts. And finally, many attempts to evaluate programs have had no longitudinal component, making it impossible to examine long-term impacts on career choices and persistence in STEM fields.

What follows in this report is a description of the program components for which there is convergent evidence of effectiveness that utilizes a variety of research designs including those that may or may not be prone to the critiques just previously described. However, regardless of the research approach, the methods will be described so that the reader can use their own discretion in drawing conclusions.

Convergent Research Findings

Across of variety of qualitative and quantitative studies on co-curricular programs and the components of them, there is emerging evidence that many programs result in participants pursuing STEM careers at higher rates than those who do not participate in intervention programs. Research, such as that of *TheScienceStudy* which has been following a panel of over 1400 URM science students for the past 8 years, are showing that engagement in co-curricular activities does in fact have long term impact on sustaining interest in science careers (Schultz, Woodcock, Estrada, Hernandez, & Chance, 2011). In this study, Research Initiative for Scientific Enhancement (RISE) program participants nationwide and a propensity score matched second cohort of students with similar interest in science, GPAs, ethnicity and socio-economic backgrounds were tracked across time to measure if their interest in bioscience careers and their engagement in STEM careers deviated across the years following their participation. Figure 1 shows that students in the RISE program maintained a stronger intention to pursue a career in the biomedical sciences than those students who were not in the program (i.e., the Match group) or those who dropped out of RISE.[2]

Other program evaluations have found similar findings regarding differences between program participants and comparison groups for a variety of programs. Some of the most well studied programs include the Biology Scholars Program at University of California, Berkeley (Matsui, Liu, & Kane, 2003), the Meyerhoff Scholars Program for STEM students (Summers & Hrabowski III, 2006), or the Howard Hughes Medical Institute Research Scholars Program at Louisiana State University which focuses upon increasing URM participation in STEM fields. Comparing program participant persistence rates with similar students who are not in the program assessed the effectiveness of these programs.[3] While tracking and measuring success is critical to showing the efficacy of co-curricular programs, more recently a second question has emerged among program directors and behavioral scientists alike, which is *why* do these programs lead to improvements in retention and persistence. The promising and convergent findings that are emerging in answer to this question can be categorized into three subcategories: (A) *program components*, (B) *psychological processes*, and the emerging (C) *culture and context*.

Caveat. These categories have permeable boundaries and many research programs span across multiple areas. In some cases psychological processes mediate the relationship between program

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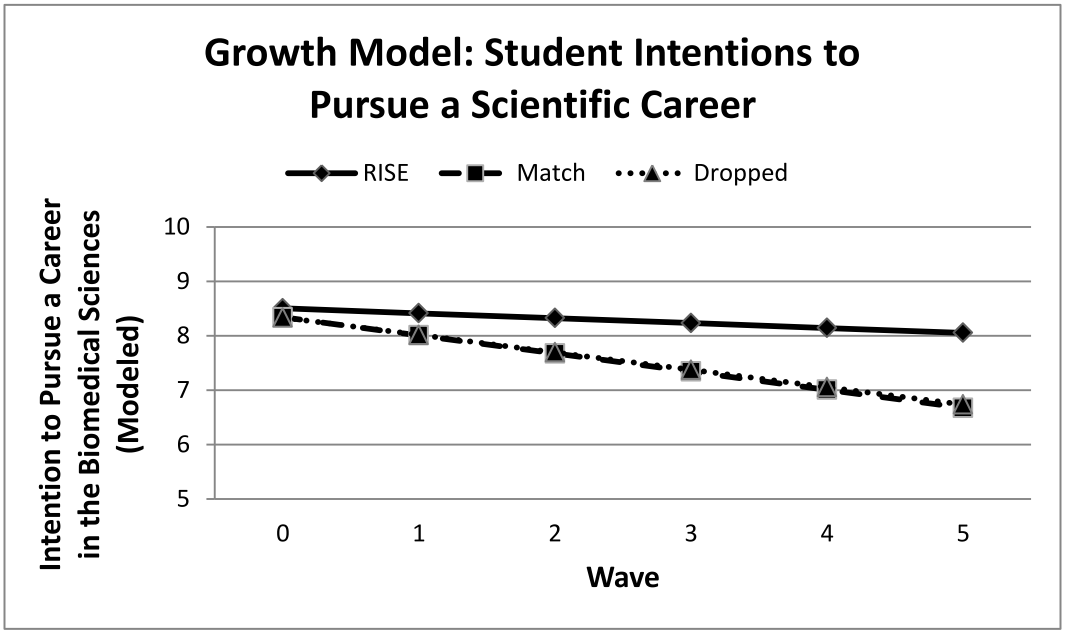
[2] "In order to identify an appropriate matched sample, we utilized a propensity score matching procedure (Rosenbaum & Rubin, 1983, 1984; West et al., 2008). The purpose of a propensity score is to provide unbiased estimates of treatment effects in a quasi-experimental design. *TheScienceStudy* conducted a large-scale recruitment survey (prior to Wave 0) to identify a potential matched panel (N = 2,166). Propensity scores were created based on 11 variables (e.g. GPA, ethnicity, intention to pursue biomedical career, first-generation status)" (Schultz et al., 2011, p. 98). Response rates at every wave have exceeded 70%.

[3] Please note that one of the critiques of such assessments is that the evaluation design can not determined to what extent program participation and selection skill are contributing to favorable outcomes.

components and increased STEM involvement (as will be described later). Acknowledging the complexity and richness of the research findings, the following will highlight the most consistent findings in each subcategory and when appropriate, summarize more complex findings.

Figure 1: TheScienceStudy Impact of Enrollment in RISE Program on Intention to Pursue Biomedical Career Across Time[4]



Program Components

Typically co-curricular support programs for undergraduate STEM students have been assessed for their overall impact and not based on how any particular component impacts student interest and persistence. However, programs for URM students offer a variety of services, experiences, and support. In addition, co-curricular programs differ in duration, program sites, and participant demographic pools. However, the majority of programs include at least one of two common elements: (a) research experience, and (b) mentorship. Many STEM professionals have impassioned stories about how a particular research experience or mentor significantly influenced their choice to pursue a STEM career. Yet, the research regarding the impact of these program attributes is not consistently as strong as general beliefs. Additionally, in the past

[4] Adapted from Schultz et al., 2011, p. 107. "Change over time analyses conducted as a hierarchical linear model, with both linear and quadratic terms. Analyses are based on students who were undergraduates (jr. or sr.) at W0. Propensity score (W0) used as time invariant covariate. RISE = students continuously funded, and MATCH = students never funded by any program and enrolled on a RISE campus. Intention to pursue career as biomedical scientist."

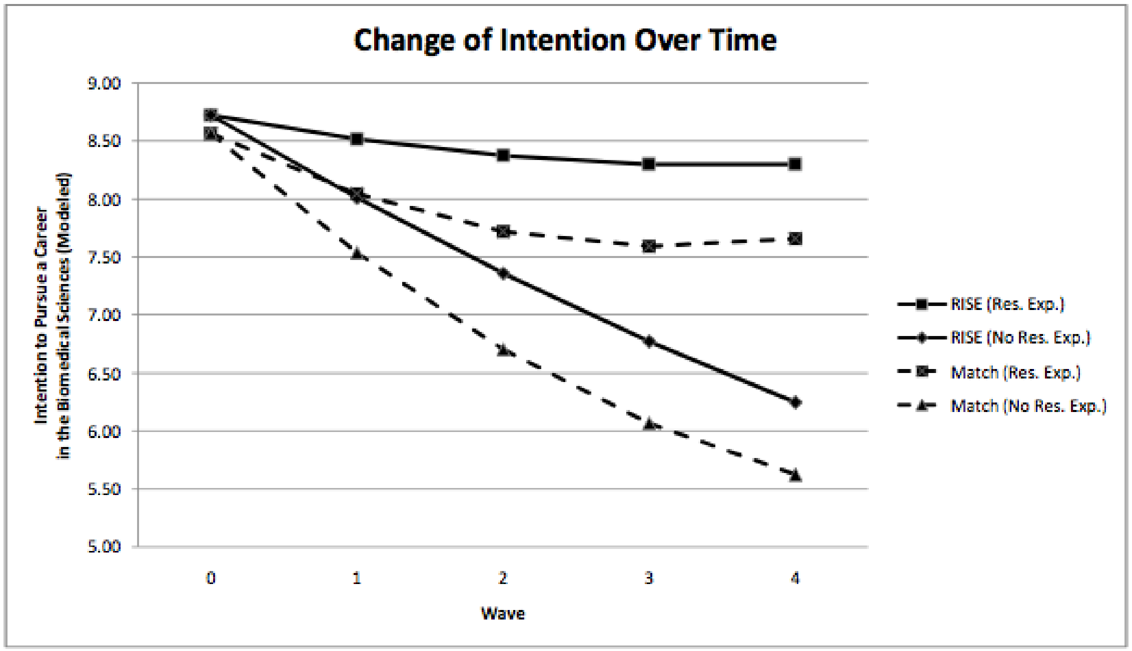
several years a third element, which will be referred to as "engaging environments" have also started to be studied. This includes specific program activities that intentionally connect students to the STEM content and career paths.

Research Experience

Across a range of age groups, program designs, intensity and duration, findings show that undergraduate research experience (in the context of co-curricular programs or within the classroom) is integral to the development and sustaining of interests in STEM careers among students. Specifically, L Laursen, Hunter, Seymour, Thiry, & Melton (2010), in their book summarizing the literature on this topic concluded that research experience positively influences career choice, placement, decision-making, and preparation. The evaluation studies they cite rely heavily on descriptive accounts of research experiences from programs with small sample sizes. While this provides great data to assess motivation and intention, there are noted limitations. Small sample sizes do not allow researchers to test if specific persons are benefitting from the research experience or account for cohort experiences (Gandara & Maxwell-Jolly, 1999; Boylan, 2006). Another significant criticism of these studies has been the inability to determine to what extent selection bias might be accounting for the impact of the research experience taking place in classrooms and co-curricular activities (Jones, Barlow, & Villarejo, 2010).

In recent years, a variety of research programs have started to show reliable impacts of research experience relating to degree completion and persistence in interest in STEM careers (Chemers, Zurbriggen, Syed, Goza, & Bearman, S., 2011; Schultz et al., 2011; Jones, Barlow, & Villarejo, 2010) using quasi-experimental designs and statistical modeling. For example, as described earlier, in the cohort of 1400 undergraduate URM students tracked across time in *TheScienceStudy*, engagement in research experience was the strongest factor found to mediate the relationship between RISE participation and persistence in science careers. As seen in Figure 2, students with research experience and no co-curricular program retained interested in science careers more strongly than those who did not engage in research and were in a co-curricular program. All students in this study had high intention to pursue a biomedical career when the study began. Interestingly, participation in this co-curricular program (i.e., the NIH RISE program) did not increase the interest of these already interested students. But rather, it buffered students from losing interest. As mentioned before, the "match" students were not enrolled in any co-curricular programs, but shared similar interest in sciences as RISE students at the beginning of the study.

Figure 2: TheScienceStudy Impact of Research Experience on Intention to Pursue Biomedical Career[5] Across Time



A very comprehensive analysis of the transcripts and admissions applications of 7,664 U.C. Davis students who declared biology as a majors between 1995-99 showed how research experience contributes towards undergraduate retention and how timing and duration of research experience also impacted retention, GPA and graduation rates (Jones, Barlow, & Villarejo, 2010). Additional research by Villarejo and colleagues also showed that participants in the Biology Undergraduate Scholars Program, an co-curricular enrichment program for underrepresented biology outperformed other students in persisting to graduation with a biology major (Barlow & Villarejo, 2004; Villarejo & Barlow, 2007). Their analyses suggested that research participation directly contributed to persistence.

Chemers' et al. (2011) study of 327 undergraduates and 338 graduate students and postdoctoral fellows described their science support experiences (research experience, mentoring, and community involvement); psychological variables (science self-efficacy, leadership/teamwork self-efficacy, and identity as a scientist); and commitment to pursue a career in scientific research. Using Structural equation modeling, results showed that for graduate students engagement in basic research experience (e.g., learning scientific language, creating own explanation for results) had different impacts than engaging in advanced research experiences

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[5] Note: Adapted from Schultz et al., 2011, p. 109. Specifics of panel describe in previous note. Research is *any* research experience ever during undergraduate education.

(e.g., authoring a research paper or training other scientists), yet both types of experiences ultimately led to sustaining commitment to a science career.

Qualitative studies, which ask students what motivated them to study STEM topics suggestions that the quality of the research experience matters (Laursen et al., 2010). This suggests that future quantitative and experimental research should assess the quality of research experiences. Specifically, characteristics that are currently being studies in quantitative and quasi-experimental studies (but not yet published) include the following:

- Authenticity. Research experience in which the outcomes are not predictable, the skill set to run the experiment requires consequential decision-making, and the results are meaningful.

- Mastery opportunity. Research opportunities that provide students with the experience of successfully completing a research activity.

- Ownership. Students publically communicate their findings to a larger community, either in the form of a poster, paper or oral presentation.

In summary, the evidence suggests that co-curricular programs with research experience component are more likely to contribute towards the development of and sustaining of interest in STEM fields. The majority of studies cited here, however, have focused on persistence in biology or biomedical fields. More research concerning the impact of research experience on engineering, mathematics and technology fields is needed. At the same time, future research may want to examine how the duration of co-curricular research experience, the time of experience in the academic career, and the quality of the research experience influences STEM interest and persistence.

Mentorship

Mentoring is the second core component of many intervention programs. Mentorship refers to a relationship between a seasoned, experienced person – a mentor – and a less experienced person – the protégé (Rhodes, 2005). Within the context of this relationship, there is the expectation that the protégé will develop professionally under the guidance of the mentor (Eby, Rhodes, & Allen, 2007). There is an assumption in the literature that mentorship is beneficial (Tennenbaum, Crosby, & Gliner, 2001) and that it results in academic achievement, productivity in scholarship, academic persistence and even psychological health (Johnson, Rose, & Schlosser, 2007). Meta-analyses of mentor-protégé studies indicate that three factors emerge as important to protégé experiencing positive outcomes (Eby et al., 2012). First, mentors can provide *instrumental support*, providing resources and opportunity to the protégé to engage in goal attainment (Kram, 1985), which can include providing access, visibility, sponsorship and other forms of career assistance. "This includes the specific mentor behaviors of providing task-related assistance, sponsorship, exposure and visibility, and coaching" (Eby et al., 2012, p. 3). Second, *psychosocial support* occurs when a mentor enhances "an individual's sense of competence, identity, and effectiveness in a professional role" (Kram, 1985, p. 32). This may also include facilitating emotional and personal development (Flaxman, Ascher, & Harrington, 1988; Nakkula & Harris, 2005). A third, *relationship quality* has been shown to be related to positive mentorship outcomes – particularly among youth and mentors. Relationship quality (sometimes as referred to as *relationship satisfaction*) is an affective assessment of liking, which may include feelings of trust, empathy, respect and connectedness (Ragins, 2010). *Most* of the empirical research showing mentorship is important to positive outcomes emerges from studies of youth mentorship and the business world (see meta analyses by Allen, Eby, Poteet, Lentz, & Lima, 2004), with the outcome of these studies typically being academic and career advancement. However, Eby et al.'s (2012) meta analysis of mentorship research coming from youth, academic and business environments shows that there is robust evidence for instrumental and psychosocial support contributing to relationship quality, in a self-enforcing cycle. And the combination of these mentorship qualities is positively related to performance, motivation, career outcomes and health for protégés. They also show, however, that instrumental and psychosocial support more strongly relates to positive outcomes than the relationship quality measure in academic contexts.

To date, there is no robust experimental evidence that mentorship results in persistence in STEM. Results from *TheScienceStudy* (previously described) provides some evidence that mentorship is related to persistence in biomedical science fields, but mentorship effects are not as strong as the effect of research experience, unless mentorship quality is also added to the model (Estrada, Hernandez, & Schultz, unpublished manuscript). Correlational results from TheScienceStudy show that having a mentor does not relate to persistence in science fields and was not significantly correlated with measures of quality mentorship. Perhaps this is because the match between mentor-protégé expectations is important. Byars-Winston et al. (unpublished manuscript), utilizing qualitative methods, found that mentor-protégé expectations are not always complementary. For instance, while URM protégés strongly believe that mentors should directly address diversity issues with them, fewer mentors agreed. This collection of research findings suggests that intervention programs need to include good communication between mentor and protégés to bridge gaps in perceptions of the goals, interpersonal communications, and role definitions.

Emergent research on this topic are taking innovative methodological approaches to better understand what type of mentorship results in optimum outcomes in the context of undergraduate co-curricular activities. To assess the mentorship of students engaged in collaborative or apprenticeship science training programs, experience sampling, throughout each day, is being collected. An additional study will be using cell-phone applications and reminder chirps to collect micro-reporting throughout the day. Students will then report mentorship experiences as they occur providing unique "real time" data regarding mentorship in the context of STEM undergraduate education.

Overall, mentorship research within the context of STEM co-curricular programs is emergent but not fully developed. A recent review of undergraduate mentoring programs concluded that future research should use more rigorous research designs to guide evidence-based mentorship practices (Gershenfeld, 2014). Clearly, there are many more questions being asked than answered. That being said, the history of research on mentorship does suggest that quality mentors, who provide instrumental and psychosocial support, and provide relationship quality, may be important in long-term STEM career success.

New Ideas for Co-Curricular Interventions: Creating Engaging Environments

Research and findings regarding engaging environments are an emerging area of study. Co-curricular programs create engaging environments when they introduce activities or context that result in students meaningfully connecting to STEM content. Studies of these approaches show how targeted interventions, which could be incorporated into co-curricular programs, can be effective in retaining interest and persistence in a variety of context. The study of engaging environments in the context of STEM co-curricular programs is occurring now, but informed by previous research on these topics in other career related fields.

Values affirmation interventions. From the field of social psychology, there has emerged Eccles's expectancy-value model (Eccles, 2009). This theory posits that if a person (a) holds the expectation that they can succeed at a task and (b) intrinsically values the engagement in the task and the utility of the task, she will be more likely to engage in challenging tasks (such as taking a honors course in high school). Eccles (2009) found that these two variables – expectation and value – reliably predicted course selections. Correlational studies also show that students who report utility value in courses are more likely to develop interest in advanced courses in those topics, which includes STEM courses (Durik, Vida, & Eccles, 2006; Harackiewicz, Barron, Tauer, & Elliot, 2002; Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008; Hulleman, Durik, Schweigert, & Harackiewicz, 2008).

Harackiewicz, Rozek, Hulleman, & Hyde, (2012) extended this research to show that a three-part utility-value intervention with high school parents affects child's persistence in STEM courses. Building on this, current research involves randomly assigning biology undergraduates to (a) affirm personal values and later to (b) focus on the relevance and utility value of their biology course material (or not) (Harackiewicz et al., 2013). Results showed improved course grades, semester grades, and persistence for first generation students (relative to continuing generation students). While this research has not directly been applied to co-curricular programs or specific activities such as research experience or mentorship, research suggests that including activities that promote utility-value could potentially impact course selection and persistence in difficult STEM courses. One simple effective intervention, which could easily be incorporated into co-curricular programs, is to have students write about the relevance of course topics to their own life (Hullman, Godes, Hendricks, & Harackiewicz, 2010; Hulleman & Harackiewicz, 2009).

Other work on value affirmations has focused on self-affirmation affecting academic performance and motivation among URM middle school students (Cook, Purdie-Vaughns, Garcia, & Cohen, 2011; Sherman et al., 2013). This work is built on the theory that when a situation is threatening, focusing upon aspects of one's identity that are valued will "fortify" self-integrity and reduce stress. They find these sorts of interventions are particularly positively impactful for URM experiencing threats to their identity. However, this work has not been extended to assess undergraduate STEM students and impacts for building resilience among this population of URM in unstudied at this time.

Belonging. Strong evidence exists that URM students' sense of belonging (sometimes referred to *social cohesion)* in academic environments is complex and often impeded (Hurtado & Carter, 1997). A sense of belonging impacts the extent to which a student integrates into the academic community, which in turn impacts intentions to persist (Hausmann, Schofield, & Wood, 2007). There is ample qualitative research documenting how women and ethnic minorities do not always find STEM academic environments a place in which they belong. Johnson (2007) found that classes conducted in large lecture halls made minority women feel "like a face in the crowd" (p. 811). He also described how course content that did not connect meaningfully to student experiences resulted in feelings of disconnect. Even anticipating entering prejudiced environment (which inherently make a person feel as if they do not belong) drains cognitive resources, increases stress and can be lead to physical and mental health issues (Sawyer et al., 2012). Similarly, analysis of a national, multi-institutional research project, titled Preparing College Students for a Diverse Democracy, found perceived racial tension reduced a sense of belonging for URMs (Locks et al., 2008). In contrast, students who have positive interactions regarding race report feeling a greater sense of belonging (Mendoza-Denton, Downey, Purdie, Davis, & Pietrzak, 2002; Lee & Davis, 2000). The issue of belonging also emerges in discussion of stereotype threat (which will be described later) in that stereotype threat environments also reduce a sense of belonging.

In terms of co-curricular activities, research experimentally manipulating belonging has only begun be conducted. However, preliminary analyses of quasi experimental data (drawn from *TheScienceStudy* described earlier) does indicate that to the extent that co-curricular activities increase a sense of belonging in STEM fields, students are more likely to persevere even if they do experience exclusion or hostility in their environment (Estrada-Hollenbeck, Woodcock, &

Schultz, 2008). These results suggest that co-curricular activities that foster belonging can buffer students from the effects of non-inclusive university or departmental environments.

Active learning. There is evidence within educational research that active learning techniques produce superior learning outcomes compared with the traditional lecture method of instruction (Handelsman, Miller & Pfund, 2006). Active techniques include exercises, activities, and discussions that engage students in problem-solving and deep processing of information. This approach to teaching has been found to be particularly effective for URM students (Stephan & Stephan, 2001).

Gasiewski, J. A., Eagan, M., Garcia, G. A., Hurtado, S., & Chang, M. J. (2012) mixed method study of 2,873 students within 73 introductory science, technology, engineering, and mathematics (STEM) courses across 15 colleges and universities found that students were more engaged in courses when instructor signaled consistently an openness to questions and recognized her/his own role in helping students succeed. Similarly, students reporting comfort with asking questions, seeking out tutoring, attending supplemental instruction sessions, and collaborating with other students were also more likely to be engaged. While this idea of adjusting STEM curriculum to incorporate more active learning opportunities is occurring because of the mounting evidence that it helps to increase student engagement and persistence, URMs. This suggests that incorporating active learning techniques into co-curricular programs may be particularly powerful. Systematic research of the effect has yet to be conducted however.

Food for Thought: STEM Co-curricular Programs as Agents of Social Influence

When students attend co-curricular STEM programs, the hope is that the program will positively influence the students to engage in and persist in STEM courses, degree programs and potentially professions. This can be understood as a context of social influence. According to Kelman and Hamilton (1989), social influence occurs when "…a person changes his or her behavior as a result of induction by some other person or group – the influencing agent" (p. 78). Social influence research focuses upon how social context effect individuals, and differs from socialization theories that focus upon individual difference measures such as personality types (Holland, 1997), or personality characteristics (Eccles, 2007). The social influence literature provides a variety of examples of how individuals are knowingly, or more often unknowingly, influenced by other people and their perception of community norms. For members of individualistic cultures, who embrace the notion that people predominantly determine their own destiny (Markus & Kitayama, 1994), the notion of being influenced can be distasteful and viewed as manipulative. Yet, social psychologists have shown that social influence is occurring all the time and in a wide array of situations (Cialdini and Goldstein, 2004; Cialdini & Trost, 1998; Chartrand & Bargh, 1999; Schultz, Nolan, Cialdini, Goldstein, Griskevicius, 2007; Nolan, Schultz, Cialdini, Goldstein & Griskevicius, 2008). The question is not: *are* students being influenced when engaging in co-curricular programs? The better question is: *how* are students being influenced? And importantly, educators and policy makers may ask, is this form of influence effectively increasing interest and persistence in STEM?

From the social influence perspective, there is an influencing agent and a target of influence (Cialdini & Trost, 1998; Kelman, 1956, 2006). In the academic environment, the influencing agents are representatives or members of the STEM academic community. The targets of influence are potential and current STEM students. Thus, the integration of a student into the STEM community fits the classic social influence paradigm. Keep this in mind when reading the following section, because not too surprisingly, many of the variables most predictive of promoting interest and persistence also are associated with integrating persons into community (Estrada, Woodcock, Hernandez, & Schultz, 2011).

Psychosocial Processes

In addition to looking at the effectiveness of specific intervention components, research on co-curricular activities seek to explain "why" a particular intervention has an impact on retention, persistence and career choice, rather than "if" it has an impact. Some important research has been done related to what integrates a student into STEM communities and motivates students to persist. These psychological variables have been found to mediate the relationship between a program components and persistence: self-efficacy, scientific identity (or identity as a scientist), values, and resilience to stereotype threat. That is to say, that as these rise, the likelihood that a particular intervention feature will result in student persistence increases as well.

Self-efficacy and Academic Perseverance

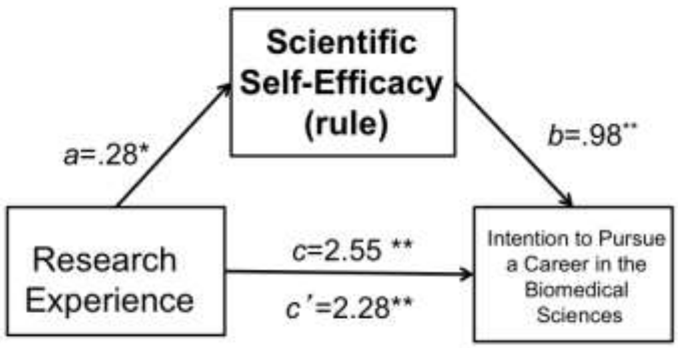
One of the most common goals of STEM co-curricular activities is to increase student skills. At the same time, one of the most widely studied psychological predictors of academic perseverance is self-efficacy (i.e, feeling one "can" engage in a particular skill). This line of research emerges from Bandura (1997) who describes self-efficacy as "the belief in one's capabilities to organize and execute courses of action required to produce given attainments" (p.3). Bandura showed that a person's self-appraisal of ability is a strong predictor of the person's likelihood to perform those actions in the future. In a series of large-scale meta-analyses examining both field and laboratory studies, and across diverse contexts and behavioral domains, self-efficacy has been shown to consistently predict behavioral outcomes and changes in individual functioning over time (see Bandura & Locke, 2003). Thus, the finding that self-efficacy enhances motivation and performance in a variety of situations -- ranging from academic (Chemers, Hu & Garcia, 2001) and athletic performance (Moritz, Feltz, Fahrbach, & Mack, 2000), to children and adolescent psychosocial functioning (Holden, Moncher, Schinke, & Barker, 1990), to minority students pursuing engineering careers (Lent et al., 2005) -- appears to be robust.

In an extension of Bandura's general theory, Lent and colleagues have argued for the importance of self-efficacy in understanding academic perseverance. To this end, they have developed and tested the social cognitive career theory (SCCT; Lent, Brown, & Hacket, 1994; Lent, 2007) in a variety of academic settings. A central feature of SCCT is that higher social support and lower social barriers contribute to the development of self-efficacy, which in turn increases interest in an academic career choice directly and indirectly through outcome expectations (Lent et al., 2005). In a study of underrepresented students, Lent showed that the SCCT predicted academic interest and goals among engineering students. In addition, studies have shown that self-efficacy consistently predicts students' interest, goals, and persistence to pursue careers in the science, technology, engineering, and mathematics (STEM) disciplines. Further, studies have shown that this model applies to both minority and non-minority students (Lent et al., 2005).

While the SCCT does not explicitly test the impact of co-curricular activities, Lent's research does suggest that to the extent that an environment increases support for being able to conduct the skills necessary for succeeds in a STEM field and decreases the perception of barriers, the more likely students will be to develop efficacy and persist in STEM fields. For example, Lent et al.'s (2003) study of 328 introductory engineering students showed that self-efficacy develops when the social environment provide high support (e.g., encouragement from friends) and low barriers (e.g., parents pressuring to change field of study). Other studies with STEM students show similar results. When the environmental feedback is positive, the student builds confidence in his or her skills, develops higher self-efficacy in that domain, and is more likely to pursue the desired behaviors than if they are given negative feedback. Lent (2007) describes this as a feedback loop where success or failure affects self-efficacy and outcome expectations, which are related to interests, intentions/goals, actions and then back to success and/or failure again. And clearly co-curricular activities have the potential to increase support and decrease barriers in a variety of ways.

Two researchers have investigated how research experience's positive relationship with persistence is mediated by self-efficacy. Chemers' et al. (2011) study using structural equation modeling, showed that science self-efficacy mediated the relationship between research experience and commitment to a science career for undergraduate and graduate URMs. Estrada (2014) research, utilizing *TheScienceStudy* panel data described earlier, showed a similar result. Specifically, the results demonstrated that when research experience results in increased science self-efficacy, intention to persist in biomedical careers also increased.

Figure 3: TheScienceStudy mediation analysis of research experience, scientific self-efficacy and intention to pursue a science career.



Note: a, b and c path's are unstandardized coefficients. * $p < .05$, ** $p < .01$
Bootstrapped indirect effect: mean = .27, $CI_{95\%}$ .06 to .56
Sobel: $Z = 2.57$, $p<.01$

Last, Byars-Winston, Pfund, Branchaw, Leverett, & Newton (under review) utilized archival data from more than 400 protégés collected from 2005-11 from several undergraduate biology research programs at a large, Midwestern research university. Path analysis of a subset of the data (which included 77% underrepresented racial/ethnic minorities) showed that perceived mentor effectiveness indirectly predicted enrollment in science-related doctoral or medical degree programs through research self-efficacy.

Future research that randomly assigns students to different types of research experience activities or mentorship approaches could provide important information to inform co-curricular programs.

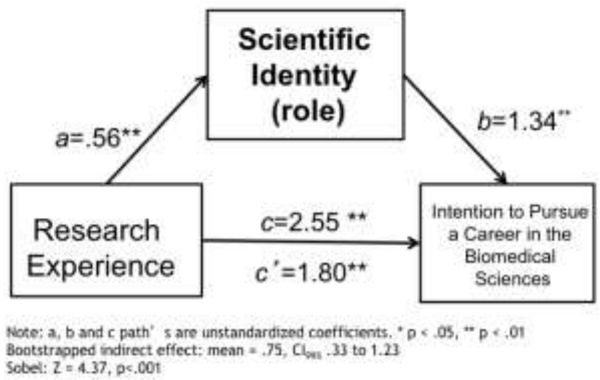
Identity as a Scientist

Tajfel and Turner (1986) introduced social identity theory as a way to explain the psychological basis of intergroup discrimination. According to this theory, each person has a variety of "social selves" that each corresponds to various circles of group membership -- such as defined by that person's gender, ethnicity, profession, religion, age, etc. Different social contexts then trigger an individual to think, feel and act in a way consist with the norms of that group to which they belong (Turner, 1982; Hogg & Vaughan, 2002).

One type of social identity can be domain identity, which sometimes develops through education or co-curricular involvement. When students have high domain identity, they report seeing themselves as members of their domain. Identification has been credited as being a strong, direct predictor of persistence in STEM(Graham et al., 2014).

Chemers et al. (2011) models suggest how co-curricular activity may contribute to the development of science identity. Contrary to expectations, the results showed that for undergraduate URMs, research experience did not predict the development of science identity. However, for graduate students, advanced research experiences (e.g., being sole author on a paper, or supervising the training of younger scientists) and socioemotional mentoring fostered the development of scientific identity, which was strongly related to commitment to a science career. Similarly, mediation analysis from *TheScienceStudy* showed that as URM students become more highly identified with science, they are more likely to persist in science careers (Estrada, 2014; see Figure 4).

Figure 4: TheScienceStudy mediation analysis of research experience, scientific identity and intention to pursue a science career.



Scientific Self-Efficacy and Identity as a Scientist. Both the work of Chemers (2011) and *TheScienceStudy* (both described earlier) provided structural equation models that had both efficacy and identity as predictors of commitment to science careers. From these works, we can see that science self-efficacy and identity do not appear to develop from the same co-curricular activities (see Chemers et al., 2011). And while both relate to persistence, efficacy drops out as a predictor of persistence when science identity is added to the model (Estrada et al., 2011). Further, results show that while self-efficacy is necessary for students to persist in STEM education, the development of their domain identity may be critical to predicting later career choice. Put more plainly, even if a student can do what your profession asks them to do, if a student does not feel a part of that profession (i.e., she does not identify herself as that kind of person), over time commitment to that profession will be more likely to wane.

Identity and Stereotype Threat

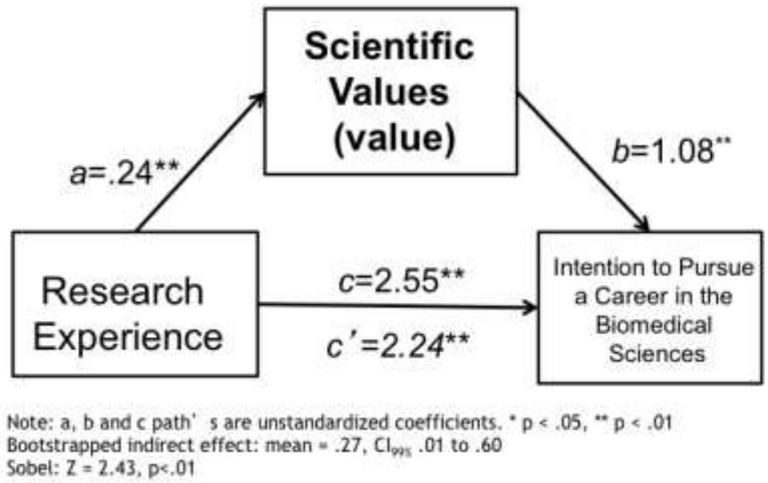
Stereotype threat research has shown that when there are "signals" or context contingencies that communicate to URM students that they do not belong in the academic or STEM community, students' performances decline while cognitive vigilance increases (Murphy, Steele & Gross, 2007). Ironically, this is particularly true for individuals who are most highly identified with the domain that provides the negative stereotype (Aronson, Lustina, Good, Keough, Steele, & Brown, 1999; Stone, 2002). Ambady, Shih, Kim, and Pittinsky (2001) showed that even among 5- to 7- year-olds and 11- to 13- year-olds, if a stereotyped identity is made salient, performance on cognitive tasks is negatively affected. Steele (1997) argues that stereotype threat prevents or breaks down a person's identification with academics, while heightening their ethnic or gender identity. This process can have a detrimental effect on academic identity, perseverance, and performance (Steele, 1997). The result is a process of academic disidentification in order to maintain positive self-esteem. Recent research has shown that this disidentification process occurs for Latino males and females as well, and that participation in co-curricular programs (in this case RISE or MARC programs), can serve to buffer students to the effects of stereotype threat (although they still experience it) (Woodcock, Hernandez, Estrada & Schultz, 2012). This research suggests that when STEM community members' attempts to influence a URM student to assume a role in their community, some URM students face unseen barriers to accepting that role. Hypothetically, the more a student acquires tools to overcome these barriers and assume the identity of a scientist, the more likely this student would be to follow the norms of that role, and to pursue a career in STEM. Direct tests of this hypothesis have yet to be conducted.

Values

Schwartz, Melech, Lehmann, Burgess, & Harris (2001) describes values as "guiding principles in people's lives" (p. 521) and focuses primarily on 10 cross-cultural value constructs. Kelman (2006), in his tripartite model of social influence, describes a variety of values held by members of any social system to which targets of influence are orienting themselves. As such, people who are newly exposed to a social system internalize these values when they authentically endorse the preferences held by the group.

In *TheScienceStudy*, internalizing the values of the science community was measured. Results showed that the more strongly students internalized scientific community values, the more likely undergraduate students were to persist in biomedical careers (Estrada et al., 2011). This is above and beyond the effects of self-efficacy and science identity development. Further, science community value endorsement mediated the relationship between engagement in research and intention to persist (similar to efficacy and identity) (see Figure 5). Last, looking at the longitudinal trajectory of value development, those students who continue to pursue science careers continue to endorse the values of the science community while those pursuing medical careers or choosing to leave science show steady declines (Estrada, 2014).

Figure 5: TheScienceStudy mediation analysis of research experience, scientific values and intention to pursue a science career.



As described earlier in this paper, using random assignment, research has shown that specific interventions that connect STEM content to student values have been particularly successful in sustaining interest and persistence (Harackiewicz et al., 2012). Emerging research is indicating that when interventions intentionally connect scientific goals to communal goals, future motivation and positivity towards science careers increases.

Putting it All Together

The research on how co-curricular activities promote and affect psychosocial variables is emerging. Using data from *TheScienceStudy*, structural equation modeling based growth curve analyses were performed to examine how co-curricular activities of undergraduate research experience and quality mentorship contributed towards the building of efficacy, identity, and values (Estrada, Hernandez & Schultz, *unpublished manuscript*). The results were nuanced. Research experience, particularly in junior and senior years, contributed to moderate growth in science identity and endorsement of science community values. Whereas quality mentorship at all time points played a small positive role increasing science self-efficacy, identity, and endorsement of science community values. Finally, results showed that while all three psychosocial variables related to pursuing a STEM career years after completing their undergraduate education, values was the strongest predictor in the SEM model.

Culture and Climate

The STEM academic culture is anecdotally described as reflecting majority group norms of celebrating independence, materialism, and the protestant work ethic. Institutional priorities and cultures can create variations on this STEM culture. For instance, there is interest in understanding the impact of Historically Black Colleges and Universities (HBCU) and Hispanic Serving Institutions (HIS) culture on student perceptions and persistence in STEM fields. Hurtado and colleagues (2011) results from a mixed methods study of science students from over 117 higher educational institutions showed that institutions vary dramatically in their cultural norms regarding student-faculty interactions. Further, they found that African American's in particular, experienced more positive climates (that is they had more interaction with faculty) at HBCU and more selective universities.

Espinosa's (2011) research, in contrast, focused on how the impact of institutional climate on women's persistence. She used hierarchical generalized linear modeling to describe the experiences of 1,250 woman of color in comparison to 891 White women attending 135 academic institutions. She founds that women of color who were successful in STEM more frequently created a supportive culture for themselves by engaging in STEM-related clubs and organizations, interacting with peers outside of classes to discuss STEM related course content, and participating in research programs. Her research shows that these activities, quite often associated with co-curricular participation, helped "women of color see beyond a STEM culture that is fraught with barriers" (p. 232).

Adding to the complexity are the "micro-climates" institution contains, such as lab and department climates, that also convey perceptions of warmth, and vary in term of their supportiveness or culture of care (Allen, 1992). Undoubtedly the culture of a discipline or institution can impact students. And it is suggested that providing a place for social interaction can be critical to sustaining student interests – especially for students who find the STEM culture dramatically different from their own. Graham et al., (2014) suggests it is critical to provide "STEM learning communities," which can be virtual or physical in structure. This community, which co-curricular programs sometimes provide, can become a gathering place that "enable students to work with and learn from each other" (p. 1126). Co-curricular programs, at their best, improve the academic culture for all students. And for URM students in particular, programs can buffer students from environmental climates that are experienced as "alien," "hostile," or "unwelcome." Systematic research to assess these impacts is not currently found in published literature, but is often described during expert discussions of this topic.

Regardless of the university, however, STEM students intentionally or incidentally learn about STEM culture as they interact with persons who represent the STEM discipline to them. And those students who persist, learn to navigate, potentially embrace, and may even eventually modify the STEM culture. How co-curricular programs create micro-climates and cultures that potentially "warm up" institutional environments deserves further study.

Implications for Future Research

As in all areas of scientific inquiry, excellence in research design and rigorous methods for collecting data are critical for developing new knowledge. Upon reviewing the existing literature, this author is struck that the majority of studies currently published on this topic involve modeling what co-curricular activities contribute towards building psychosocial variables that lead to persistence in STEM fields. In rare cases there is emerging research using quasi-experimental designs (e.g., using propensity score matched groups) to test the effects of participation in co curricular programs across time. For some particular activities, there is some random assignment and testing of effects. However, this is the least common type of research at this time. Studies that randomly assign students to participate in co-curricular activities, measure psychosocial variables, and measure intention and STEM engagement behaviors have yet to be conducted and published.

To contribute towards diversifying and refining the research being used to study these important questions, the follow suggests were made by national researchers in this field:

- Track students over time (i.e., using traditional longitudinal, and accelerated longitudinal methods) to assess both short-term and long-term impacts of program elements across the academic pipeline.
- Collect data from similar cohorts of students who do not participate in the program as a comparison or control group.
- Utilize objective outcome measures such as grades, knowledge assessments, degree conferment and discipline of study.
- In-depth case studies or focus groups with program participants and similar students to track experiences at time of participation and shortly after (i.e., prospective studies).
- Move beyond linear models and explore decision points at which time individuals and attributes of the context lead to binary (yes/no) decision switches.
- When possible, utilize random assignment to co-curricular program groups.
- Designing randomized controlled interventions that compare the impacts of long versus brief engagement in program elements.

Undoubtedly, multi-disciplinary approaches and sophisticated analysis strategies are necessary to truly understand and test co-curricular program impacts on short-term and long-term STEM career persistence.

Conclusion

The study of the benefits of co-curricular programs and the more intensive investigation of "why" some programs lead to long term improvement in retention and persistence and others do not is truly an emerging literature. While there are a variety of co-curricular programs and activities that exist, this report has focused less on specific program evaluations and more on the characteristics of programs that have shown consistent improvement of student persistence and retention – particularly of URM students. Second, this paper has sought to describe some of the psychosocial variables that predict persistence in STEM fields. And last, the paper briefly describes some of the cultural and climate issues that might particularly lead to the alienation of URM students. Importantly, there is evidence that these elements work in concert with each other. Co-curricular programs occur in a cultural context – which can be a university, a department, or even a geographic community. Further, activities of co-curricular programs can impact the development of student psychosocial experiences such as efficacy, identity, and values, which relate to increased persistence and commitment to STEM careers. And while trends in research findings are highlighted in this paper, importantly, much more research is going to emerge in the coming years to refine and expand what is written here.[6] Undoubtedly, a revision of this paper will be necessary in 10 years that will likely be twice as long.

[6] Please note that this author is aware of at least 8 National Institutes of Health studies currently funded that include comparison groups, longitudinal designs, and outcomes that are both self-report and behavioral milestones such as GPA, degree attainments, and graduate school attendance. However, as the data is only now being collected, it is premature to report findings here.

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