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The Role of Efficacy and Identity in Science Career Commitment Among Underrepresented Minority Students

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A web-based survey of members of the Society for the Advancement of Chicanos and Native Americans in Science tested a model that proposed that the effects of science support experiences on commitment to science careers would be mediated by science self-efficacy and identity as a scientist. A sample 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. Structural equation model analyses supported our predictions. Among the undergraduates, science (but not leadership/teamwork), self-efficacy, and identity as a scientist fully mediated the effects of science support experiences and were strong predictors of commitment. Results for the graduate/postdoctoral sample revealed a very similar pattern of results, with the added finding that all three psychological mediators, including leadership/teamwork self-efficacy, predicted commitment.

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At the time the study was conducted, all authors were in the Department of Psychology at the University of California, Santa Cruz (UCSC), with the exception of Barbara K. Goza, who was at the Educational Partnership Center at UCSC. Moin Syed is now in the Department of Psychology at the University of Minnesota, and Barbara K. Goza is now in the Department of Psychology at UCSC.

Despite much discussion and many efforts at change, the representation of Native Americans, African–Americans, and Latino Americans in science fields is still quite low. This is true at all points in the academic pipeline, including completing of bachelor's degrees, entering graduate programs, and completing graduate programs in science. Over the last 15–20 years, change has occurred, but not at a sufficient level (Gándara & Maxwell-Jolly, 1999; Treisman, 1992). Equity in science education is of concern internationally (Baker, 1998; Smith, 2010); however, the current article addresses the issue with respect to education in the United States.

Attempts to redress these inequities have most often involved the development of "science support" programs, in which underrepresented students or young professionals receive guidance and encouragement to pursue a career in scientific research. The typical program model and components embedded in these programs were highlighted by Gándara and Maxwell-Jolly (1999), and include professional experiences such as research, mentoring, as well as academic, financial, and psychosocial support. Specific programs that have been lauded as achieving notable successes in enhancing minority undergraduate performance in the sciences and promoting subsequent graduate school attendance and success include the Meyerhoff Scholars Program at University of Maryland, Baltimore County (Maton, Hrabowski, & Schmitt, 2000) and the Biology Undergraduate Scholars Program (BUSP) at University of California, Davis (Barlow & Villarejo, 2004; see also Hurtado et al., 2011, for a fuller discussion of programmatic and institutional features affecting student outcomes).

Although some programs have been effective in helping some students, an empirical basis for a nuanced understanding about how and why the "better" programs are effective has been lacking. Without targeted theory and empirically established findings, new programs and programs seeking to improve results have only intuitive and anecdotal guides. In recent years, there has been a call for more intensive, theory-based research on the underlying processes that affect underrepresented minority (URM) students' commitment and success.

The design of the present research is based on our belief that the most powerful tool for building better science support programs is a deep understanding of the processes that underlie student decision-making and performance. In the current research, we are not so much interested in programs per se, as in the experiences and opportunities they provide, which could occur outside the programs as well. We examine how psychological factors, such as self-efficacy and personal identity, mediate the relationships between science support experiences (such as research experience, mentoring, and community involvement) and desirable outcomes (such as commitment to and effort expended toward a career in scientific research). We present, here, a "mediation model" of how these program and psychological variables are predicted to combine to produce greater commitment to a scientific career (Figure 1).

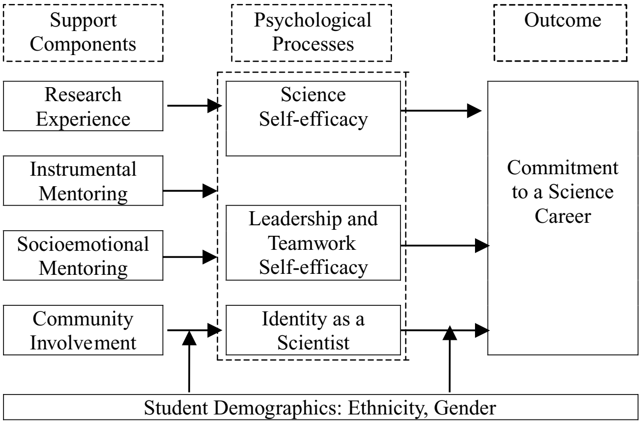


Fig. 1. Mediation model of the effects of science support experiences, adapted from Chemers et al. (2010).

The Mediation Model of the Effects of Science Support Experiences

The model that we propose is one in which science support experiences affect relevant psychological processes, which in turn lead to commitment and involvement in a scientific career. We focused on several important science support experiences: research experience, mentor influences, and community involvement. Three key mediators are tested: science self-efficacy, leadership and team work self-efficacy, and identity as a scientist.

Research experience. A growing body of evidence supports the assumption that involving students in doing research promotes learning outcomes. Sadler, Burgin, McKinney, and Punjuan (2010) synthesized 53 studies of research apprenticeships. Research experiences were found to enhance attitudes such as interest in science careers and self-efficacy regarding research skills, and students who were engaged in the more complex aspects of the research process, such as analysis, showed gains in scientific reasoning (e.g., Charney et al., 2007; Ryder & Leach, 1999). In addition to those reported by Sadler et al. (2010), a number of studies have addressed the effectiveness of science support programs that include a research component. Merna Villarejo and her colleagues reported the evaluation of the BUSP, an educational enrichment program for underrepresented biology students at the University of California Davis (Barlow & Villarejo, 2004; Villarejo & Barlow, 2007). They found BUSP students outperformed others in general chemistry and calculus and in persisting to graduation with a biology major. Their analyses suggested that this persistence may be due to BUSP students' high rates of research participation. In a related survey of high-achieving BUSP alumni, Villarejo, Barlow, Kogan, Veazey, and Sweeney (2008) found that among those who pursued PhDs in biomedical research, over half indicated that their experience in undergraduate research was transformative.

Similarly, Maton et al. (2000) analyzed the effect of the Meyerhoff Scholars Program for African–American students at the University of Maryland, Baltimore County. Compared with multiple relevant samples, Meyerhoff students achieved higher grade point averages, graduated from science and engineering majors at higher rates, and had higher rates of admittance to graduate school. Students reported that research internships and mentors were among the experiences responsible for their success. A follow-up study found that participation in on-campus, academic year research was associated with substantial increases in science, technology, engineering, and mathematics (i.e., STEM) PhD pursuit (Carter, Mandell, & Maton, 2009).

Mentor influences. Among the program components empirically identified as elements of effective science support programs are mentor relationships between science faculty and undergraduate and graduate protégés. High school students also have opportunities to experience research apprenticeships, which usually include a mentoring component. Investigations are exploring the nature of mentoring, and how mentoring influences students in high school, undergraduate, and graduate work (Linnehan, 2001; Tenenbaum, Crosby, & Gliner, 2001). These studies have shown that mentored students demonstrate higher academic performance, attendance, and satisfaction. For example, Witkow and Fuligni (2011) describe how failure to get good advice about career and educational planning for some high school students influences their future educational trajectories. Similarly, Phinney, Torres Campos, Kallemeyn, and Kim (2011) discuss the critical role of effective mentoring for first-year college students. A study by Foertsch, Alexander, and Penberthy (2000) compared program design features with outcomes for participants in summer research programs at 15 midwestern research universities. The study found that the pivotal factor in determining summer interns' success was the quality of the relationship with the faculty mentor, even when the actual number of contact hours with the faculty member was limited.

Community involvement. We use the term community involvement to reflect opportunities that might be available for a student to develop a sense of being part of the scientific community, one aspect of the psychosocial support element identified by Gándara and Maxwell-Jolly (1999). Work contact that goes beyond formal lectures or assignments might allow a student to get to know better the faculty, postdoctoral fellows, graduate students, and undergraduate peers who have chosen scientific research as a major or a career. Additionally, social events (such as pizza parties, picnics, etc.) that are part of many programs provide an alternative context for developing a network. At a national level, many organizations with the goal of broadening participation in science offer conferences that bring students, faculty, and professional scientists together.

It has been assumed that these science support program components (i.e., research experience, mentoring, and community involvement) contribute to success, but the psychological processes involved are not well understood. From both a policy and a practice perspective, understanding the underlying psychological mechanisms provides guidance to select new programs for funding and to improve the effectiveness of existing programs. A serious question, then, is what are the pathways by which mentoring and other science support activities affect student commitment and performance in science education contexts? In this study we focused on three relevant constructs: science self-efficacy, leadership and teamwork self-efficacy (LTSE), and identity as a scientist.

Science self-efficacy. Based on an extensive literature on commitment and achievement in academic performance environments, academic self-efficacy is a good candidate as a probable mediator of the effects of science support activities. A vast program of research on self-efficacy (Bandura, 1997) indicates that confidence in one's ability to perform a specific behavior or accomplish a specific task is predictive of performance above and beyond predictions based on objective measures of ability alone. Self-efficacy has been related to persistence, tenacity, and achievement in both educational and experimental settings (Bandura, 1986; Zimmerman, 1989). Chemers, Hu, and Garcia (2001) applied efficacy theory to predict academic success and personal adjustment of first-year university students. Based on assessments near the beginning and end of the academic year, the findings indicated that, above and beyond any effects of previous ability, academic self-efficacy was a strong and significant predictor of academic goals, academic performance, personal adjustment, and health.

Most programs designed to increase minority student representation and academic performance in the sciences place a great deal of emphasis on an authentic research experience. As indicated above, some studies have examined how research apprenticeships affect the knowledge and skills of science learners at the high school and undergraduate levels (Barab & Hay, 2000; Bell, Blair, Crawford, & Lederman, 2003; Kardash, 2000; Richmond & Kurth, 1999; Seymour, Hunter, Laursen & Deantoni, 2004). These studies found that engagement in authentic science offers the opportunity for students to use scientific and technical language, communicate about the problems of science, and appreciate the actual work of science. Our hypothesis is that a significant contributor to successful academic (and professional) work in science depends on the possession of high self-efficacy for science skills, and that science self-efficacy will fully mediate the effects of science experiences on student commitment and performance.

Leadership and teamwork self-efficacy. We argue for the inclusion of leadership and teamwork efficacy as an important mediator on the grounds that most research, particularly in the STEM fields, is conducted by teams (i.e., lab groups) rather than individuals working alone.

Almost 50 years ago, Hagstrom (1964) argued that "teamwork is necessary in science" (p. 242), due to the collection of skills necessary to solve a problem and/or the need for faster, more efficient problem solving than individuals can accomplish. Over this 50-year period, the proportion of team-produced scientific publications and patents has increased dramatically (Wuchty, Jones, & Uzzi, 2007). Practical advice for managing scientific teamwork is now available in print (see, e.g., Barker, 2002; Boss & Eckert, 2003; Harmening, 2003) and from many professional associations (see websites of the American Psychological Association, *American Chemical Society*, and the *Society for the Advancement of Chicanos and Native Americans in Science* [*SACNAS*] for examples). A budding field called the science of team science aims to enhance the productivity of large-scale collaborative research and training programs. However, little research has been done regarding the impact of interpersonal processes such as leadership and teamwork on scientific collaboration (Stokols, Hall, Taylor, & Moser, 2008). When a student is exposed to the importance of leadership, as modeled by mentors, and teamwork, as modeled by peers, s/he may come to recognize that to be a good scientist also involves being a good team member.

As science self-efficacy is critical to sustaining students' success in science, so too is leadership/teamwork self-efficacy. A series of studies by Chemers and his associates indicates that leadership efficacy has effects, similar to those observed in the academic domain, on leader and team performance (Chemers, Watson, & May, 2000; Watson, Chemers, & Preiser, 2001). If leadership efficacy promotes successful performance in scientific endeavors, it is reasonable to expect that positive beliefs about one's leadership self-efficacy should contribute to students' expectations of success in a science career. Those expectations should in turn contribute to commitment to such a career.

Identity as a scientist. Erikson (1968) and Arnett (2004) proposed that the optimal developmental outcome for adolescents and emerging adults is to achieve a sense of coherence that integrates their multiple identities across time and contexts. Azmitia, Syed, and Radmacher (2008) further argued that developing an identity can be confusing and stressful, because of the multiple worlds and identities to which a college student is exposed. "One source of confusion is whether a person's unique, or personal, self develops in connection with his or her sense of identity and belonging to a group or collective (i.e., a social identity)" (p. 3) (see also Syed, Azmitia & Cooper, 2011, for extensive coverage of identity and academic integration).

The empirical literature on student persistence and success in academic settings reports that identification is related to a sense of fit with other academics and the academic world in general (Dovidio, Gartner, Niemann, & Snider, 2001). A number of studies have found that identification with context relevant identities (e.g., student, scientist, etc.) provides better prediction of academic performance and persistence than racial or ethnic identity (Bonous-Hammarth, 2000; Eccles & Barber, 1999; Osborne & Walker, 2006). Eccles and Barber (1999) found that underrepresented minorities who identify strongly with academic role identities have greater persistence to degree completion than do underrepresented students who identify more strongly with their social identities (e.g., ethnic/racial, gender, socioeconomic status). Franco-Zamudio (2010) reported that a large proportion of the successful graduate students that she studied belonged to some organization that combined their academic and personal identities (e.g., Women in Engineering Society, Hispanic Scientists).

The foregoing interpretation of the relevant literature led to the proposed model of research experience, i.e., that the experiences of research participation, mentoring, and involvement in a community of science will enhance commitment to a career in science, but only if they positively affect science self-efficacy, LTSE, and science identity; in other words, a model of full mediation by self-relevant attitudes.

Previous Research with the Mediation Model of the Effects of Science Support Experiences

Chemers et al. (2010) reported the findings of two studies of undergraduate students enrolled in research support programs at the University of California, Santa Cruz. The first study involved a retrospective survey of past participants in science support programs as well as students enrolled in science and engineering majors during the same time period, but who did not participate in programs. Following the model outlined in Figure 1 and described above, the researchers predicted that science and leadership/teamwork self-efficacy and identity as a scientist would mediate the effects of science support activities on commitment to continue as a scientist. The science support activities that were significant predictors included research experience, community involvement, and instrumental mentoring, but not academic support, financial support, or the socioemotional aspect of mentoring. Among the psychological mediators, science self-efficacy and identity as a scientist, but not leadership/teamwork self-efficacy had effects strong enough to be included in the final path model. The second study conducted by Chemers et al. (2010) tested the same model using a prospective design and yielded similar findings. The analyses indicated a plausible chain of effects in which research experience and instrumental mentoring lead to higher levels of science self-efficacy, which leads to enhanced identity as a scientist, which leads to stronger commitment to a science career.

These studies provided strong support for the role of science self-efficacy and identity as a scientist as psychological mediators of science support activities on commitment to a career in science. They also supported the value of research experience and at least some aspects of mentoring. Despite this general support for the mediation model, some hypothesized relationships (e.g., the effect of leadership/teamwork self-efficacy) were not found. In addition, the sample was limited to undergraduates studying at one university, and the sample size in Study 2 was small. Thus, it would be useful to conduct additional research involving broader, nationally distributed samples of undergraduates and postbaccalaureates, from a diverse group of colleges, universities, and graduate schools.

The current study is a replication and extension of the earlier studies reported in Chemers et al. (2010), designed to build on those findings. Through the auspices of the *SACNAS* we were able to survey a large sample of underrepresented participants at the undergraduate, graduate, and postdoctoral levels. *SACNAS* was founded in 1973, dedicated to helping Hispanic/Chicano and Native American scientists succeed in obtaining the advanced degrees necessary for science research, leadership, and teaching careers at all levels. The centerpiece of *SACNAS* programming is the annual conference that brings together over 2000 participants in scientific symposia, keynote speakers, career advancement workshops, exhibits, student research presentations, and mentoring. In addition, *SACNAS* supports about 45 local chapters on college and university campuses across the country. The *SACNAS News* publishes mentoring and science information for 17,000 readers nationally. Targets of these interventions include undergraduate and graduate students, postdoctoral scholars, and science educators at K-12, community college, and university levels.

Based on Chemers et al.'s (2010) earlier studies, we employed the mediation model (Figure 1) to predict that the psychological variables of science self-efficacy, LTSE, and identity as a scientist will mediate the effects of science support experiences (research experience, mentoring, and community involvement) on commitment to a science career. We expect to replicate the findings of the earlier research. We are also interested in whether, with a sample that is more diverse in several ways, including age/stage of science education, we would find effects of leadership/teamwork self-efficacy, and of socioemotional mentoring. For example, it seems plausible that because graduate students and postdoctoral fellows have more experience than undergraduate students in working as part of a scientific team, LTSE might emerge as a significant mediator for those students and fellows.

Method

Participants

Participants were recruited from the *SACNAS*. In December 2006, *SACNAS* staff members sent e-mail invitations on behalf of the *SACNAS* Board, describing their collaboration on a research project to "help us learn about the 'active ingredients' that support science students most effectively." The invitation indicated that the survey is for anyone connected with *SACNAS* who is currently an undergraduate, graduate student, or postdoctoral fellow, or anyone who has graduated from college or university in the last 3 years. Two reminder invitations were sent over the following month. All individuals in the *SACNAS* database received the invitation, although the available information in the database suggested that there were 4,101 members who met the survey eligibility criteria, of whom 1,944 had updated their e-mail addresses since the beginning of 2006. Participants completing the entire survey included 242 current undergraduates, 85 who had earned bachelor's degrees within the last 3 years, 278 graduate students, and 60 postdoctoral fellows. These 665 participants represent a response rate of 16.22% of eligible participants and 34.21% of those with likely current addresses. For purposes of this study, recent graduates were grouped with undergraduates because many faculty and graduate programs recommend that students delay graduate admissions 2 or 3 years postbaccalaureate, so that students gain work experience and assess continuing science interests. Postdoctoral fellows were grouped with graduate students.

Among the 327 undergraduates/recent graduates who completed the entire survey, there were 67% females, with a mean age of 24.06 years (SD = 5.67). Ethnicity was quite diverse, with 160 (49%) reporting Latino/Hispanic heritage, 28 (9%) Black/African–American, 14 (4%) Native American, 38 (12%) mixed URMs (Latin, Black, Native American), 47 (15%) Asian American or Pacific Islander, and 36 (11%) White. Although 231 (71%) were born in the United States, only 163 (50%) spoke English as their first language.

Of the 338 graduates and postdoctoral fellows who completed the entire survey, 63% were female, with a mean age of 29.83 years (SD = 6.61). Reported ethnic background was 192 (57%) Latino, 24 (7%) Black/African–American, 16 (5%) Native American, and 60 (18%) mixed URMs; 23 (7%) Asian American or Pacific Islander, and 20 (6%) White. Most (240 or 71%) were born in the United States, and 194 (57%) spoke English as their first language.

Measures

The surveys included numerous constructs. Those reported in this article were adaptations of the scales used in Chemers et al. (2010). Most of the constructs and items were the same across undergraduate and graduate/postdoctoral versions, with variations described below. Initial analyses were conducted to ensure that each construct was a single factor, and items not loading on the construct were deleted from further analysis.

Science support experiences. To isolate the effects of student engagement in extracurricular activities such as science support program interventions, items requested students to consider how active they were as undergraduates (or graduate students/postdoctoral fellows) outside regular coursework. Students reported their involvement using a 5-point scale, ranging from 1 (*not at all*) to 5 (*a lot*).

Research experience. For undergraduates, 10 items measured students' involvement in professional science activities of varying levels of complexity. Sample items include "I learned scientific language and terminology" and "I created my own explanation for the results of a study/research project." Cronbach's alpha was .93. For graduate students, we added 11 items of a more advanced nature, such as "I was sole or first author on a paper or poster presentation on scientific content at a meeting of a professional organization" and "I supervised and trained undergraduate or graduate students." The resulting two-factor structure included a 6-item basic research construct (α=.92) and a 14-item advanced research construct (α=.85).

Community involvement. Community involvement was measured for undergraduates with a four-item scale including items such as "I networked with fellow students," and I participated in social events with faculty or staff members, and/or fellow students." For graduate students and postdoctoral scholars, one of these items did not load with community involvement resulting in three-item scale. In both cases, Cronbach's alpha coefficients were sufficiently high (.80 for undergraduates and .76 for graduates/postdocs).

Socioemotional and instrumental mentoring. The Chemers et al. (2010) measures were built on earlier work by Tenenbaum et al. (2001) and Kram (1985). We assessed two functions of mentoring: socioemotional mentoring that supports students' emotional development, and instrumental mentoring that helps students learn essential tasks of science career development. Mentors were defined as "anyone more experienced than you who has given you individual support related to your development as a science student." Students were invited to think back to possible mentoring from faculty members, program staff, graduate students, or peers, including people who were not formally designated as mentors, and describe the extent to which their mentor(s) provided them with opportunities. Students responded on a 5-point Likert-type response scale, with higher values indicating greater opportunities.

The undergraduate and graduate student versions of the socioemotional mentoring scale were exactly the same, consisting of seven stems such as "given you the impression that they believed in you" and "earned your trust" (Cronbach's alphas = .94 for undergraduates and .95 for graduates). For the instrumental mentoring scale, six items included stems such as “taught you specific research or analysis skills” and “helped you figure out for yourself how to answer a research question.” For graduate students, five stems were added to assess more advanced professional activities, such as “helped you with job searches (by reviewing your application materials, watching practice talks, providing feedback, etc.)” and “gave you advice about good conferences to attend” (Cronbach’s alphas = .90 for undergraduates and .92 for graduates).

Psychological processes.

Science self-efficacy. Building on the work of Bandura (1997), Chemers et al. (2010), and Kardash (2000), the science self-efficacy scale assessed students’ confidence in their abilities to function as a scientist. Students indicated the “extent to which you are confident you can successfully complete the following tasks.” For undergraduates, a 10-item scale parallels the research experience scale, including “use scientific language and terminology” and “create explanations for the results of a study.” For graduate students and postdoctoral fellows, these 10 items were augmented with three more advanced items such as “publish research in peer-review outlets.” Students responded on a 5-point scale that ranged from 1 (*not at all confident*) to 5 (*absolutely confident*), resulting in Cronbach’s alphas of .94 and .95 for undergraduates and graduates, respectively.

Leadership/teamwork self-efficacy. This scale, adapted from Chemers’ program of research (Chemers et al., 2000, 2010; Watson et al., 2001), invited students to report on their confidence in leading and working on a research team. Leadership was defined as “getting people to work together effectively to answer a question or solve a problem (e.g., motivating good performance, dealing with conflict, etc.).” Teamwork was described as including communication and collaboration, such as “I know how to cooperate effectively as a member of a team.” Students responded on a 5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), with a Cronbach’s alpha of .90 for both undergraduates and graduates.

Identity as a scientist. The Chemers et al. (2010) scale was based on the work of Sellers (see, e.g., Sellers, Smith, Shelton, Rowley, & Chavous, 1998) and Luhtanen and Crocker (1992) as well as interviews. Students were asked to think about themselves and their personal identity, to help us “understand how much you think that being a scientist is part of who you are.” On a 5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), students indicated their agreement to six items such as “In general, being a scientist is an important part of my self-image,” and “I am a scientist” (α=.89 for undergraduates and .90 for graduates).

Outcome: Commitment to a science career. The outcome variable in this survey was developed to measure students’ intentions to work in the field of science. Both undergraduates and graduate students responded to seven items on a

5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Items included "I intend to work in a field of scientific research" (α=.96 for undergraduates and .94 for graduates).

Results

Analysis Strategy

The conceptual model was tested through a series of path analyses using maximum likelihood estimation in EQS 6.1 (Bentler, 2004). Several fit statistics were used to assess how adequately the model represented the covariance matrix. The chi-square goodness-of-fit test was used because it is helpful for comparing nested models. However, because the chi-square statistic is greatly affected by sample size, we also present the normed chi-square (NC), which is the chi-square divided by the number of parameters. The chi-square statistic should be nonsignificant and the NC less than 2.0. The remaining fit indices were a mix of incremental, absolute, and residual-based indices. Incremental indices included the comparative fit index (CFI) and nonnormal fit index (NNFI), which compare the model being tested to an independence model. The additional advantage of the NNFI over the CFI is that it corrects for the number of parameters in the model (Hu & Bentler, 1995). The goodness of fit index (GFI) is an absolute-fit index that represents the proportion of variance in the covariance matrix that is accounted for by the model. Higher values of the CFI, NNFI, and GFI are indicative of better fit, with values above .90 generally preferred. Last, we consulted the root mean square error of approximation (RMSEA) as a residual-based index. Lower values of the RMSEA reflect better model fit, with values less than .08 considered acceptable (Kline, 2005).

The base model tested was the conceptual model (Figure 1), which specifies that psychological processes (i.e., identity, science self-efficacy, and leadership/teamwork self-efficacy) mediate the association between program components (i.e., research experience, instrumental mentoring, socioemotional mentoring, community involvement) and commitment to a science career. This model was tested first, rather than a model that included direct effects from program components to commitment, due to the previously established support for the mediational model (Chemers et al., 2010). To maximize statistical power, we first ran a series of regression analyses to determine whether any variables could be removed from the analysis (see below). Once we moved to the path analyses, all nonsignificant paths were dropped based on the results of the base model, and the Lagrange multiplier tests and standardized residuals were consulted regarding the need for adding unspecified paths.

Table 1. Means, Standard Deviations, and Bivariate Correlations for Undergraduate Sample

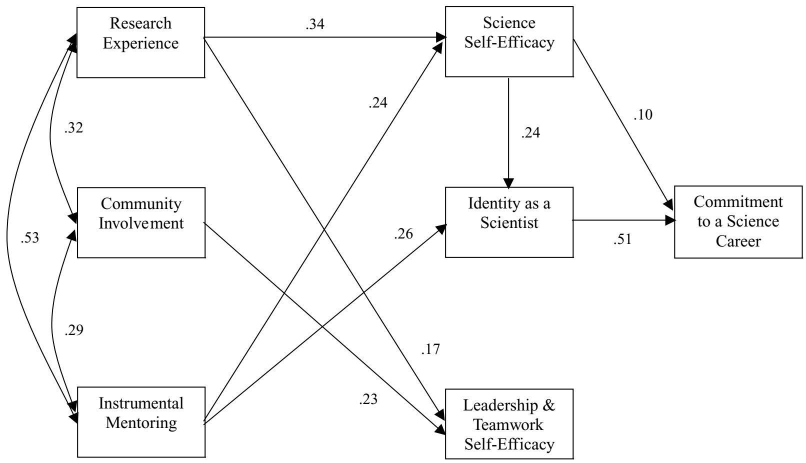
	M	*SD*	1	2	3	4	5	6	7
1. Research experience	3.57	1.02	–						
2. Instrumental mentoring	3.70	0.95	.55	–					
3. Socioemotional mentoring	3.84	0.99	.34	.70	–				
4. Community involvement	3.37	1.02	.32	.30	.25	–			
5. Science self-efficacy	3.89	0.74	.48	.44	.31	.19	–		
6. Leadership and teamwork self-efficacy	4.42	0.52	.23	.24	.23	.28	.30	–	
7. Identity as a scientist	4.01	0.76	.24	.35	.27	.14	.34	.18	–
8. Commitment to a science career	4.53	0.74	.15	.28	.23	.11	.30	.20	.55

Note. rs $> .11, p < .05$; rs $> .14, p < .01$; rs $> .18, p < .001$.

Undergraduate Sample

Descriptive statistics and intercorrelations are presented in Table 1.The preliminary multiple regression analyses indicated that socioemotional mentoring did not predict commitment or any of the three mediators, so it was dropped from further analysis. Thus, the base model tested for the undergraduate sample was the conceptual model without socioemotional mentoring as an exogenous predictor. Fit indices for the mediation model indicated a good fit, $\chi^2(5) = 16.11$, $p = .007$, NC = 3.22, CFI = .98, NNFI = .90, GFI = .97, RMSEA = .08 (90% C.I. = .04, .13). The modification indices did not indicate that fit would be improved by adding direct paths from program components to commitment. However, there were several nonsignificant paths in the full mediation model. Accordingly, the next model we tested was a trimmed mediation model that removed all nonsignificant paths. The fit for this model was excellent, $\chi^2(10) = 22.20$, $p = .01$, NC = 2.22, CFI = .97, NNFI = .94, GFI = .97, RMSEA = .06 (90% C.I. = .03, .10). Furthermore, this model did not have significantly worse fit than the previous full mediation model, $\Delta\chi^2(5) = 6.09$, $p = .30$, yet is more parsimonious.

This final trimmed model (Figure 2) indicated that science self-efficacy fully mediated the association between two of the program components (research experience and instrumental mentoring) and commitment. Identity was also a mediator of the association between instrumental mentoring and commitment. Further, although science self-efficacy had a modest direct path to commitment (β=.10), identity also acted as a partial mediator of this association. Last, both research experience and community involvement predicted leadership/teamwork self-efficacy, but because the latter did not have a direct path to commitment there was no association to mediate.



Model Fit: χ^2 (10) = 22.20, p = .01, CFI = .97, IFI = .97, GFI = .98, NNFI = .94, RMR = .02, RMSEA = .06 (.03, .10), AIC = 2.20

Fig. 2. Results for the undergraduate sample. All paths are significant at $p < .05$.

Table 2. Means, Standard Deviations, and Bivariate Correlations; Graduate Student/ Postdoctoral Fellow Sample

	M	*SD*	1	2	3	4	5	6	7	8
1. Research experience	4.09	0.95	–							
2. Advanced research experience	2.61	0.85	.53	–						
3. Instrumental mentoring	3.23	0.97	.41	.47	–					
4. Socioemotional mentoring	3.47	1.18	.22	.16	.67	–				
5. Community involvement	3.58	0.97	.23	.40	.32	.23	–			
6. Science self-efficacy	3.97	0.74	.50	.48	.44	.23	.29	–		
7. Leadership and teamwork self-efficacy	4.40	0.53	.28	.29	.34	.33	.28	.46	–	
8. Identity as a scientist	3.97	0.79	.18	.29	.30	.28	.24	.38	.34	–
9. Commitment to a science career	4.38	0.74	.12	.18	.30	.23	.22	.37	.35	.58

Note. rs > .11, p < .05; rs > .14, p < .01; rs > .18, p < .001.

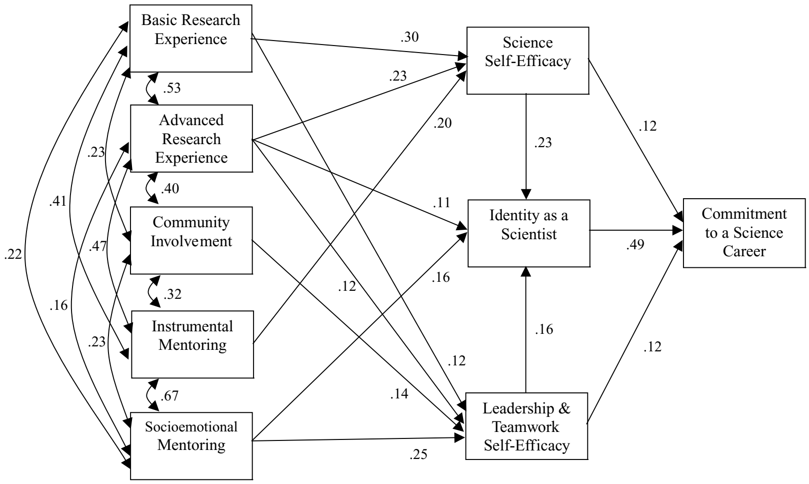
Graduate Student/Postdoctoral Fellow Sample

Descriptive statistics and intercorrelations are presented in Table 2.The models for the graduate/postdoc sample were tested using the same procedures as for the undergraduate sample. One difference between the two models was that the “research experience” predictor was separated into two new predictors, “basic research experience” and “advanced research experience” to reflect the wider variety of experiences and skills needed at the graduate/postdoctoral level.

Preliminary regression analyses indicated that all variables should be retained, so the base model is the conceptual model illustrated in Figure 1 (although with the addition of the advanced research experience variable). The test of the mediation model suggested acceptable fit, $\chi^2(7) = 53.95$, $p < .001$, NC = 7.71, CFI = .95, NNFI = .95, GFI = .97, RMSEA = .14 (90% C.I. = .11, .18). The modification indices did not indicate that fit would be improved by adding direct paths from program components to commitment.

The next model we tested dropped all nonsignificant paths from the previous full mediation model. This model had good fit, $\chi^2(13) = 62.26$, $p < .001$, NC = 4.79, CFI = .95, NNFI = .86, GFI = .96, RMSEA = .10 (90% C.I. = .08, .13), and was not significantly worse than the previous model despite its relative parsimony, $\Delta\chi^2(6) = 8.31$, $p = .21$. Examination of the standardized residuals indicated two major sources of poor fit. One was the lack of a path between leadership/teamwork self-efficacy and identity, suggesting that, like science self-efficacy, identity at least partially mediates the association between leadership/teamwork self-efficacy and commitment. Adding this path was a significant improvement in fit over the previous model, $\Delta\chi^2(1) = 7.72$, $p = .006$. However, the RMSEA was still high (.10, 90% C.I. = .08, .13), and the NNFI was a bit low (.87). Reexamining the standardized residuals indicated that there was only one source of poor fit: the unmodeled association between science self-efficacy and leadership/teamwork self-efficacy, for which we have no a priori expectations about causal flow. Although it is important to use caution when correlating error terms, in this case it may be reasonable to do so as both constructs tap into efficacious beliefs and share similar item structure and content. Adding the path between the errors improved fit dramatically, $\Delta\chi^2(1) = 36.41$, $p < .001$, for a final model fit of $\chi^2(11) = 18.02$, $p = .08$, NC = 1.64, CFI = .99, NNFI = .98, GFI = .99, RMSEA = .04 (90% C.I. = .00, .08).

The final model (Figure 3) contains a set of findings that very closely approximate the conceptual model. The effects of program elements on commitment were fully mediated by the psychological variables: science self-efficacy mediated the paths from basic research experience, advanced research experience, and instrumental mentoring; identity mediated the paths from advanced research experience and socioemotional mentoring; and leadership/teamwork self-efficacy mediated the paths from basic and advanced research experience, community involvement, and socioemotional mentoring. Moreover, the three psychological mediators of science self-efficacy, leadership/teamwork self-efficacy, and identity each independently predicted commitment. However, identity also partially mediated the association between both domains of self-efficacy and commitment.



Model Fit: χ^2 (12) = 54.42, p < .001, CFI = .96, IFI = .96, GFI = .97, NNFI = .87, RMR = .03, RMSEA = .10 (.08, .13), AIC = 30.42

Fig. 3. Results for the graduate/postdoc sample. All paths are significant at $p < .05$.

Discussion

The current study offered an extension and refinement of a mediation model that is suggestive of possible causal effects in underrepresented students' science career commitment. The model includes the effects of various support structures and processes designed to prepare students for research careers in science, such as hands-on research experience, mentoring, and community involvement (i.e., interactions with professionals and peers who are involved in research and/or in scientific education). The model proposes that the effects of these support mechanisms are fully mediated by students' psychological reactions to the mechanisms in terms of self-efficacy and identity.

Initial tests of the model were reported in an earlier study by Chemers et al. (2010). Chemers et al. conducted retrospective and prospective studies of undergraduates, surveying students who had either majored in science or engineering and/or were participants in science support programs during the period 1999–2004. As reported in the introduction to this article, the Chemers et al. (2010) study provided strong support for the model.

In the present research, we sought to replicate the Chemers et al. (2010) findings and to extend the model beyond undergraduates to more advanced members of the science education community, i.e., graduate students and postdoctoral fellows. Our findings provide strong support for the mediation model for both groups of students, but especially for the more advanced students. The path analyses shown in Figure 2 (for undergraduates) and Figure 3 (for the graduate students and postdoctoral fellows, combined) again demonstrate that the effects of science support activities on commitment to a career in science are fully mediated by science self-efficacy and identity as a scientist. Even more striking are the results for the more advanced sample, which are remarkably similar to the predicted model, including significant pathways for the effects of leadership/teamwork self-efficacy that were not seen earlier.

In the current study, LTSE enters the model for both undergraduate and graduate/postdoc samples. For the undergraduates, higher levels of research experience and mentoring are associated with higher levels of LTSE, but LTSE has no direct or indirect connections to commitment. On the other hand, for the graduate post/doctoral sample, these variables, as well as community involvement, are associated with LTSE, and LTSE has both a direct and an indirect (through science identity) connection to commitment. Why might this be so?

Chemers et al. (2010) posited that the reason they failed to obtained effects of LTSE, even though predicted, was that the undergraduates they studied may not have had sufficient experience with team-based research to recognize and value the effects of teamwork. That explanation is consistent with our finding of partial mediation effects for LTSE in the more advanced sample. The undergraduate sample evidences a connection between their science support experiences and their own LTSE, though those connections do not extend to enhancement of commitment. One possible line of reasoning might be that the *SACNAS* membership, the majority of which is Latino and Native American, might be more oriented toward and sensitive to social relations (i.e., teamwork) in research teams, because of the greater focus on social relations in more collectivist cultural communities (Markus & Kitayama, 1991). Much more extensive research will be needed to understand fully these distinctions.

The strength and coherence of the replications and extensions in this study dramatically increase our certainty of the productive research value of self-efficacy and personal identity in studies of motivation, commitment, and performance of underrepresented students, and all students, in the science education pipeline.

Future Research

Our findings point to some important directions for future research. One complex, but fascinating, set of questions relates to whether or not ethnic differences might have important moderating effects on these findings. Chemers et al. (2010) compared White and URM students in their analyses and found very few differences. Nonetheless, there are many theoretical perspectives that might predict such differences (Chemers & Murphy, 1995; Markus & Kitayama, 1991).

One perspective highlights the potential role of cultural differences that might make communication and understanding more difficult. Markus and Kitayama (1991) have examined differences and similarities between individuals who have been raised in individualistic and collectivist societies. They report difference between these groups in cognitive, emotional, and motivational domains. In her model of the multicultural organization Mai-Dalton (1993) addresses these same difficulties and concludes that the degree of assimilation into the dominant culture is related to the strength of negative experiences. URM students in the United States occupy a range of levels of cultural assimilation.

Another perspective is concerned with the obstacles and barriers that face some individuals in educational and organizational settings. A large and growing body of work on "stereotype threat" has shown that negative stereotypes and expectations for one's social group or category (e.g., URM or gender) can engender anxiety, poor performance, and withdrawal from situations and endeavors that make the threat salient (Steele & Aronson, 1995). Chemers and Murphy (1995) reviewed the literature relating to organizational leadership of American ethnic minorities and found that while actual differences between minority and dominant group members are small, stereotypes and negative expectations often create obstacles and difficulties for minority employees in U.S. organizations. Both perspectives (cultural differences and barriers/threats) might affect both a sense of competency and personal identity, which our research finds to be critical aspects of career commitment (see also Syed et al., 2011).

In all of the data reported thus far, the effects of mentoring are strong, with instrumental mentoring having stronger effects than socioemotional mentoring. Aside from this distinction, however, we know very little about the specific behaviors, paths, and contexts of successful mentoring (see also Blake-Beard, Bayne, Crosby, & Muller, 2011). A better understanding of mentoring could help program faculty and staff provide training to improve the effects of mentoring. Mentoring, of one kind or another, was a strong predictor in all four studies, but the effects for instrumental mentoring were generally stronger. We want to understand more about why this is, and when each type of mentoring is helpful.

Some research directions could go a long way to enhancing both the internal and external validity of research findings. Internal validity could be addressed powerfully by the use of true experiments with random assignment of participants to various science support experiences. We recognize that such a suggestion is controversial. Program directors have expressed concern about turning away any student who might benefit from the experience. However, our colleagues in mental health research employ the "waiting list control group" design. Because mental health programs are chronically understaffed relative to the demand for services, some clients must be put on a waiting list for treatment when resources permit. If assignment to the waiting list were random, it could serve as a valid control group.

One such study (Nagda, Gregerman, Jonides, von Hippel, & Lerner, 1998) of programmatic support for students was conducted at the University of Michigan where the cohort of African–American students was relatively large. More students requested admission into the program than could be accommodated, so among all students whose credentials reached threshold for inclusion in the program, participants were chosen at random. Their methodology allowed them to draw strong conclusions about student persistence and to determine which students benefitted most from program support (i.e., second-year African–Americans whose academic performance was lower than their African–American peers).

Long-range follow ups of study participants could be a contributor to greater external validity. The demonstration of long-range effects on important outcomes (e.g., progress through the pipeline, performance in terms of grades, presentation, and publications) would help to authenticate the role of psychological variables in prediction of such effects.

The close replication of the Chemers et al. (2010) study in the current study creates more certainty about the importance of the targeted mediators (self-efficacy and identity), which should lead to greater attention to and greater targeted efforts at producing these effects by program faculty and staff. As in many studies of student performance, mentoring played an important role. However, we have not identified the particular aspects or behaviors that mentors should follow. Further research in this area will add substantive practical value to the mediation model.

Our study also has implications for policy level decisions. This is a productive research area with even greater potential for helping to broaden participation of underrepresented populations in scientific careers. On this basis, we would argue for maintaining high levels of research funding to encourage subsequent research. If further study supports our findings, science support funding agencies might begin to mandate attention to psychological mediators in program proposals.

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