Longitudinal Associations Among Undergraduates’ Research Experience, Self-Efficacy, and Identity

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Abstract: Prior research shows that undergraduates tend to identify more strongly with the field of science after participating in scientific research. However, mediators that might account for this association are not well understood. In the current study, we propose that science self-efficacy may serve this meditational function. Specifically, data from a 2-year longitudinal study were used to test a model in which science self-efficacy was expected to mediate the association between research involvement and identity as a scientist. The ethnically diverse sample included 251 undergraduates who were recruited from colleges and universities across the United States. The hypothesized mediation model was tested with a cross-lagged panel analysis. As expected, greater levels of research experience at Time 1 predicted higher identity as a scientist at Time 3, and this association was mediated by science self-efficacy at Time 2. Exploratory analyses testing for ethnic and gender differences in the model suggested that the associations in the model were similar for undergraduates from diverse backgrounds. From a theoretical standpoint, the current study provides novel insight into how research experience, efficacy, and identity relate to one another over time. Applied implications center on the importance of involving undergraduates in research that has the potential to bolster their science self-efficacy. © 2015 Wiley Periodicals, Inc. J Res Sci Teach 52: 847–867, 2015

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The United States is currently struggling to populate the science workforce with qualified individuals. Reversing this trend has become a national priority for several reasons. First, scientific innovation is associated with competitiveness in the global economy (National Science Board, 2003; Zakaria, 2011), which implies that building the science workforce ought to have positive implications at the national level. Second, careers in science fields tend to be high paying and prestigious. Thus, improving access to these fields is likely to have positive implications at the individual level as well (Handelsman et al., 2004).

Undergraduates are a population of particular interest in the effort to combat shortages in the science workforce (Graham, Frederick, Byars-Winson, Hunter, & Handelsman, 2013). This is because many students who enter college with the goal of obtaining a science degree ultimately switch majors or leave higher education altogether (U.S. Department of Education, 2013). For this reason, it is critical to understand how undergraduates come to incorporate “scientist” into their...
identity (Aschbacher, Li, & Roth, 2010; Hunter, Laursen, & Seymour, 2006). The current study aims to shed light on this process by examining data collected from undergraduates over the course of 2 years. Specifically, we test a mediation model in which research involvement predicts greater science self-efficacy, which in turn predicts stronger identity as a scientist (see Figure 1 for a depiction of the conceptual model). Although aspects of this model have been considered in prior research (e.g., Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011), the current study is the first to examine how research experience, efficacy, and identity relate to one another over time. This is an important innovation because longitudinal data allow for especially rigorous tests of mediation and causal direction (see Cole & Maxwell, 2003). Furthermore, the use of longitudinal data provides insight into the long term implications of undergraduates’ research involvement.

Below, the constructs and associations in the hypothesized model are described in more detail. First, we explain our conceptualization of identity as a scientist and provide an overview of prior studies demonstrating that involvement in research can enhance the extent to which undergraduates view themselves as scientists. We then explain why we expect science self-efficacy to mediate the association between research involvement and identity as a scientist. Lastly, we describe our hypotheses and highlight the advantages of testing them with longitudinal data.

Identity as a Scientist

Theorists have long noted that choosing a career path is a key developmental milestone. For example, Arnett (2004) argued that deciding between potential careers is a defining feature of emerging adulthood, which is an exploration-focused stage of development that takes place from the late teens through the twenties (see also Erikson, 1968; Grotevant & Cooper, 1986; Low, Yoon, Roberts, & Rounds, 2005). The importance of selecting a particular career path is especially relevant for emerging adults who attend college (Arnett, 2004). This is because much emphasis is placed on picking an academic major that will serve as preparation for a future career. Thus, for both developmental and contextual reasons, it should come as little surprise that academic preferences are a salient facet of identity for many undergraduates (Syed, 2010).

Identity itself can be defined as one’s integrated sense of self across time and across contexts (Erikson, 1968). The current study focused on the extent to which undergraduates view “scientist” as a core component of their identity. We refer to this construct as identity as a scientist. Our conceptualization of identity as a scientist aligns with prior work in the

![Figure 1](image-url)
fields of education and psychology. For instance, Brickhouse, Lowery, and Schultz (2000) noted that identity as a scientist is informed by students’ perceptions of who they are and who they hope to become with respect to science. Along a similar vein, Erikson (1968) underscored the importance of forming a coherent identity, which involves forging ties between academic pursuits and one’s broader sense of self.

Identity as a scientist has been linked to positive outcomes such as expected and actual persistence in the science pipeline (e.g., Aschbacher et al., 2010; Chemers et al., 2011; Hazari, Sonnert, Sadler, & Shanahan, 2010; Perez, Cromley, & Kaplan, 2014). As a result, the question of how it can be fostered within undergraduates has garnered considerable attention. Especially promising is research that has identified links between involvement in scientific research and subsequent gains in identity as a scientist (Aschbacher et al., 2010; Charney et al., 2007; Hunter et al., 2006).

From a situated learning perspective (e.g., Lave & Wenger, 1991), research experience likely fosters identity as a scientist because it serves to integrate students into a science-related community of practice through exposure to more experienced scientists. An example of this integration process is described in Hunter et al.’s (2006) assessment of an intensive summer research experience. When students were asked to describe the gains they made over the course of the program, many noted that they had learned to think and work like scientists. This sentiment was mirrored in responses from students’ faculty mentors. Specifically, some mentors reported that over the course of the program, students developed an identity and skillset that characterizes emerging scholars in the field of science. Similar findings have been obtained in studies examining the benefits of research experience within the context of academic outreach programs. For example, one study found that student-faculty research partnerships brought underrepresented ethnic minority students into the fabric of the university, which resulted in greater retention (Nagda, Gregerman, Jonides, von Hippel, & Lerner, 1998; see also Barlow & Villarejo, 2004; Chemers et al., 2011).

Does a Mediator Explain the Connection Between Research Experience and Identity as a Scientist?

Although prior studies have linked research experience to identity as a scientist, key questions remain. Of particular note is variation in the extent to which research experience is beneficial for students (Kardash, 2000; Sadler, Burgin, McKinney, & Ponjuan, 2010). For example, some students who participate in academic outreach programs as undergraduates eventually attend graduate school in science fields, whereas others leave the science pipeline altogether (e.g., Estrada, Woodcock, Hernandez, & Schultz, 2010). The sources of this variation are not fully understood. One means of providing insight into this issue is to determine whether there is a mediator that accounts for the association between research experience and identity as a scientist. If a mediator exists, then variation in the effects of research experience could be attributed to the extent to which research experience influences the mediator.

In a recent review, Sadler et al. (2010) suggested that science self-efficacy may be responsible for mediating the positive effects of research experience. However, they qualified their discussion of this possibility by arguing that it needs to be substantiated through empirical research (see also Brown, Lent, Ryan, & McPartland, 1996). The current study responds to this call by testing a longitudinal model in which science self-efficacy mediates the association between research experience and identity as a scientist (see Figure 1). In other words, we expected that involvement in research would lead to heightened science self-efficacy, which would in turn lead to enhanced identity as a scientist.

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Science Self-Efficacy as a Mediator

According to Bandura (1997), self-efficacy is a person’s belief in her or his ability to realize a particular goal or outcome. Thus, science self-efficacy reflects one’s self-perceived likelihood of successfully completing tasks within the realm of science. Although self-efficacy is related to academic ability, they are distinct constructs. For instance, prior research indicates that efficacy predicts academic outcomes even after controlling for ability indicators such as grades and test scores (e.g., Chemers, Hu, & Garcia, 2001).

If science self-efficacy does in fact mediate the association between research experience and identity as a scientist, it ought to be significantly associated with both constructs. Namely, as shown in Figure 1, we would anticipate two significant associations: research experience—efficacy and efficacy—identity. The theoretical and empirical grounding for these predictions is described below.

Research Experience as a Predictor of Science Self-Efficacy

In the model advanced in the current study, research experience was expected to predict science self-efficacy. There is strong theoretical and empirical precedent for this prediction. From a theoretical standpoint, efficacy is thought to stem from sources such as mastery experience and vicarious learning, which often characterize undergraduates’ experiences in research laboratories (Lent & Brown, 2006). For example, undergraduates involved in authentic scientific research usually work toward mastering skills, and they have opportunities to watch others in the lab persevere in the face of challenges (Hunter et al., 2006). From an empirical standpoint, several studies have linked undergraduates’ involvement in research to increases in their science self-efficacy (for a review, see Sadler et al., 2010). For example, Kardash (2000) found that after a summer research experience, undergraduates displayed greater efficacy in domains such as interpreting data and orally communicating findings (see also Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013). Similarly, results from qualitative research suggest that many undergraduates cite heightened confidence in their science abilities as a key benefit derived from their research involvement (Hunter et al., 2006; Seymour, Hunter, Laursen, & Deantoni, 2004).

Science Self-Efficacy as a Predictor of Identity as a Scientist

The hypothesized model also includes an association between students’ science self-efficacy and their identity as a scientist. Specifically, we anticipated that science self-efficacy would predict subsequent levels of identity as a scientist. The theoretical grounding for this expectation was guided by Brown and Lent’s (2006) social-cognitive career theory, which is a career-focused adaptation of Bandura’s (1997) work on self-efficacy. One of Brown and Lent’s main assertions is that self-efficacy shapes academic and career preferences, which are closely linked to academic identity (e.g., Chemers et al., 2011; Hazari et al., 2010; Syed et al., 2013). Qualitative research yields additional support for the prediction that science self-efficacy will predict identity as a scientist. For instance, Aschbacher et al. (2010) found that students’ identity as a scientist waned when they did not perceive themselves as capable of success in their science classes, which led the authors to suggest that there is “an important relationship between science identity, self-confidence, and perceived ability in science.” (p. 572). Similarly, undergraduates in a study conducted by Seymour et al. (2004) reported that increased confidence in their science abilities contributed to their sense of becoming a scientist. Lastly, research examining attrition in science majors finds that declines in science self-efficacy often precede women’s disidentification with science (e.g., Margolis, Fisher, & Miller, 2000).
Although qualitative research provides evidence of a potential link between science self-efficacy and identity as a scientist, this association has received little attention in quantitative studies. Accordingly, an important goal of the present study was to shed additional light on the nature of this association. In particular, the current study is uniquely positioned to provide insight into the directionality of the association between efficacy and identity through its use of longitudinal data (see Cole & Maxwell, 2003).

The Present Study

The overarching goal of the present study was to examine how research experience, science self-efficacy, and identity as a scientist relate to one another over time. Prior research shows that research involvement is associated with heightened identity as a scientist (e.g., Aschbacher et al., 2010), and some scholars have suggested that science self-efficacy may mediate this association (see Sadler et al., 2010). Based on this work, the current study was designed to test the following hypothesis: Science self-efficacy will mediate the association between research experience and identity as a scientist. Put differently, we expected that greater involvement in research at Time 1 would predict significantly higher identity as a scientist two years later at Time 3. Moreover, we anticipated that science self-efficacy at Time 2 would mediate this association (see Figure 1). Because women and ethnic minority students tend to be underrepresented in science fields (AAUW, 2010), we also conducted exploratory analyses examining whether paths in the model were moderated by participants’ ethnic background or gender.

Although the mediating role of science self-efficacy has been explored in at least one prior study (see Chemers et al., 2011), the current study is the first to test for mediation with longitudinal data. This is an important distinction because there is growing consensus among methodologists that tests of mediation will be biased unless they utilize longitudinal data (Cole & Maxwell, 2003; Maxwell & Cole, 2007). In part, this is because establishing temporal precedence is inherent in questions relating to mediation (MacKinnon, Lockwood, & Williams, 2004). Drawing from Cole and Maxwell’s (2003) recommendations, the current study takes into account temporal precedence by examining whether research experience predicts change in science self-efficacy and, similarly, whether science self-efficacy predicts change in identity as a scientist. Our use of longitudinal data is also advantageous because it allows for an examination of the directionality of the associations among research experience, efficacy, and identity. Specifically, we compare the hypothesized model to two competing models with alternate directional associations (see Cole & Maxwell, 2003; Kline, 2006).

Method

Participants

Participants were undergraduates who attended a variety of colleges and universities throughout the United States. They were recruited through the Society for the Advancement of Hispanics/Chicanos and Native Americans in Science (SACNAS).1 Specifically, students who had registered for the SACNAS research conference in 2010 (Cohort 1) and 2011 (Cohort 2) received e-mails soliciting their participation. Notably, some participants presented research at the SACNAS conference, but others did not. Hence, participants had a range of prior research experience at Time 1. In the recruiting e-mails, the study was described as a project designed to “help us learn about the ‘active ingredients’ that support science students most effectively.” To incentivize participation across all time-points, participants were told that they would receive one $50 gift certificate after Year 1 of the study and another after Year 2.

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The original sample included 806 participants, which reflects a 40% response rate at Time 1. In total, 309 participants provided data at all three time-points. From this pool of 309 participants, 56 (18%) were removed because they were already at ceiling on the Time 1 identity as a scientist measure. Thus, the forthcoming analyses focus on 251 participants (Cohort 1: \( n = 140 \); Cohort 2: \( n = 111 \)). Preliminary analyses (detailed below) demonstrated that the two cohorts did not differ in their mean levels of research experience, efficacy, or identity at any time-point. Hence, they were grouped together in the analyses. At Time 1, the mean age of the sample was 22.61 years (\( SD = 5.18 \); range = 18–54), and most participants were juniors (40%) or seniors (45%); however, frosh (1%) and sophomores (14%) also participated. Many participants were still undergraduates when data collection concluded, although a sizeable minority (39%) had graduated and moved into the workforce, post-baccalaureate programs, or graduate school. With respect to area of study, a plurality of participants were pursuing degrees related to biology (38%); other common majors included math (11%), biochemistry (10%), chemistry (9%), and computer science (5%).

Just over half of the participants were first-generation college students. Specifically, 55% reported that neither of their parents had graduated from college. Women comprised 67% of the sample, and participants identified as members of the following ethnic groups: African American (8%), Asian American (20%), European American (35%), Latino/a (49%), and Native American/Indigenous (17%). Overall, 69% of participants identified as a member of at least one underrepresented ethnic group. These participants were compared to participants who identified as Asian American or European American in the multiple-group comparisons that tested for ethnic differences in the hypothesized model.

Procedure and Measures

Students who agreed to participate completed an online survey at each time-point. The surveys took most participants about 30 minutes to complete. Participants who completed the full study were followed for nearly 2 years. For Cohort 1, data collection occurred during Summer/Fall 2010 (T1), Spring 2011 (T2), and Spring 2012 (T3). Similarly, for Cohort 2, data collection occurred during Summer/Fall 2011 (T1), Spring 2012 (T2), and Spring 2013 (T3). These measurement occasions were selected for several reasons. First, the Time 1 data were collected just prior to the SACNAS research conference. Thus, this was arguably a time when many of participants were obtaining the research experiences that we endeavored to study. The Time 2 and Time 3 measurement occasions were selected because we had an interest in examining the long term implications of research involvement. Furthermore, because efficacy and identity develop gradually, we wanted to ensure that the hypothesized mediation effect had sufficient time to emerge (see Cole & Maxwell, 2003).

The three measures used in the current study have all been used in prior research conducted by Martin Chemers and his colleagues (Chemers et al., 2011; see also Chemers et al., 2001; Syed, Goza, Chemers, & Zurbriggen, 2012). To create these measures, Chemers began by drawing from theory and empirical research to generate a preliminary set of items. Particularly influential papers include Kardash’s (2000) examination of undergraduate research participation, which informed the research experience measure; Bandura’s (1997) work on self-efficacy, which informed the science self-efficacy measure; and Sellers’s work on racial identity (e.g., Sellers, Smith, Shelton, Rowley, & Chavons, 1998), which informed the identity as a scientist measure.

After items for each measure had been generated, interviews were used to gauge their appropriateness for students in science fields. The following groups of people participated in the interviews: faculty from university science departments; undergraduates from science majors; and university staff members from science outreach programs. Interview responses were discussed by the research team and integrated into the pilot survey. The pilot survey was then...
administered using a think-aloud protocol (e.g., Ericsson & Simon, 1998) to a new group of undergraduates, who provided further feedback about terminology and response alternatives. Lastly, the pilot survey was formally administered to students in science majors, and tests such as factor analysis were used to identify and discard items that were problematic (e.g., due to high cross-loadings). The resultant measures were used in the current study and are described in more detail below.

**Research Experience.** Participants read a list of 10 research tasks such as “I learned technical science skills” and “I had the opportunity to generate my own research question to answer.” They then rated their level of involvement in each research activity outside of their regular coursework. Ratings could range from 1 (not at all) to 5 (a lot). Psychometric analyses revealed two problematic items and indicated that the 5-point scale should be converted to a 4-point scale. Hence, the final research experience measure included eight items that were measured on a scale ranging from 1 (not at all / a little) to 4 (a lot).

**Science Self-Efficacy.** Participants read a list of 10 research tasks that paralleled items used in the research experience scale. In this case, however, participants rated their confidence in their ability to complete each research task. Ratings could range from 1 (not at all confident) to 5 (absolutely confident). Psychometric analyses revealed three problematic items and indicated that the 5-point scale should be converted to a 4-point scale. Hence, the final science self-efficacy measure included seven items that were measured on a scale ranging from 1 (not at all / a little) to 4 (a lot).

**Identity as a Scientist.** Participants were asked to think about their identity with the goal of “helping us understand how much you think that being a scientist is part of who you are.” They then rated their agreement with five items such as “In general, being a scientist is an important part of my self-image” and “I am a scientist.” Ratings could range from 1 (strongly disagree) to 5 (strongly agree). Psychometric analyses indicated that the 5-point scale should be converted to a 4-point scale. Hence, the final identity as a scientist measure included five items that were measured on a scale ranging from 1 (not at all / a little) to 4 (a lot).

To determine whether research experience, efficacy, and identity could be empirically distinguished, exploratory factor analyses with varimax rotation and principle components extraction were carried out at each time-point. Findings illustrated that the three measures cleanly loaded onto three separate factors. The factor structure did not substantially differ over time or according to participant background characteristics. For illustrative purposes, results of the Time 1 factor analysis are depicted in Table 1.

**Results**

The current study’s findings are organized into three sections. First, we report the results of a Rasch analysis, which provides insight into the psychometric properties of the measures used in the current study. Preliminary analyses are then described. Lastly, the hypothesized mediation model is tested with cross-lagged panel analysis.

**Rasch Analysis**

The current study’s first analytic step was a polytomous Rasch analysis, which was necessary for two main reasons. First, Rasch analysis allows researchers to gauge whether the psychometric properties of their measures are sound. For example, it can be used to identify ill-fitting items and assess differential item functioning across time-points. Second, Rasch analysis transforms ordinal data into interval data, thus making it suitable for parametric analyses that require linearity (Bond & Fox, 2007; Boone, Townsend, & Staver, 2010).
All Rasch analyses were carried out using Winsteps version 3.81. Each analytic step was derived from Mallinson’s (2011) guidelines for applying Rasch analysis to repeated-measures data. Preliminary analyses revealed that for several items across all three measures, fewer than 10 participants endorsed “1” on the rating scale, which can contribute to unreliable Rasch estimates (Bond & Fox, 2007). The rating scale was therefore transformed from a 5-point scale to a 4-point scale by combining the “1” and “2” response categories.

To ensure that the three measures functioned adequately for the duration of the study, they were separately assessed at each of the three time-points. Wright and Linacre (1994) recommend

__Table 1__

*Factor structure of study variables at Time 1*

<table>
<thead>
<tr>
<th>F1</th>
<th>F2</th>
<th>F3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1: Research Experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prompt: “Please describe how active you have been in the following science related activities while you’ve been an undergraduate. We are interested in science-related activities that occurred OUTSIDE of your regular coursework.”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. I worked on a research project in which I figured out what data to collect and how to collect it</td>
<td>0.78</td>
<td>0.15</td>
</tr>
<tr>
<td>2. I reported my research results in an oral presentation or written report</td>
<td>0.73</td>
<td>0.25</td>
</tr>
<tr>
<td>3. I learned scientific language and terminology</td>
<td>0.71</td>
<td>0.08</td>
</tr>
<tr>
<td>4. I related my research results and explanations to the work of others</td>
<td>0.69</td>
<td>0.44</td>
</tr>
<tr>
<td>5. I used scientific literature to guide a research project</td>
<td>0.68</td>
<td>0.43</td>
</tr>
<tr>
<td>6. I had the opportunity to generate my own research question to answer</td>
<td>0.68</td>
<td>0.21</td>
</tr>
<tr>
<td>7. I learned technical science skills</td>
<td>0.67</td>
<td>0.04</td>
</tr>
<tr>
<td>8. I took a leadership role in a scientific research team</td>
<td>0.57</td>
<td>0.38</td>
</tr>
<tr>
<td>Factor 2: Science Self-Efficacy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prompt: “Indicate the extent to which you are confident that you can complete the following tasks.”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Relate results and explanations to the work of others</td>
<td>0.20</td>
<td>0.84</td>
</tr>
<tr>
<td>2. Generate a research question to answer</td>
<td>0.13</td>
<td>0.79</td>
</tr>
<tr>
<td>3. Use scientific literature to guide research</td>
<td>0.23</td>
<td>0.78</td>
</tr>
<tr>
<td>4. Create explanations for the results of the study</td>
<td>0.30</td>
<td>0.75</td>
</tr>
<tr>
<td>5. Develop theories (integrate results from multiple studies)</td>
<td>0.25</td>
<td>0.73</td>
</tr>
<tr>
<td>6. Use scientific language and terminology</td>
<td>0.16</td>
<td>0.55</td>
</tr>
<tr>
<td>7. Use technical science skills</td>
<td>0.31</td>
<td>0.47</td>
</tr>
<tr>
<td>Factor 3: Identity as a Scientist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prompt: “The following questions ask how you think about yourself and your personal identity. We want to understand how much you think that being a scientist is part of who you are.”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. In general, being a scientist is an important part of my self-image</td>
<td>0.17</td>
<td>0.12</td>
</tr>
<tr>
<td>2. Being a scientist is an important reflection of who I am</td>
<td>0.11</td>
<td>0.16</td>
</tr>
<tr>
<td>3. I feel like I belong in the field of science</td>
<td>0.13</td>
<td>0.11</td>
</tr>
<tr>
<td>4. I have a strong sense of belonging to the community of scientists</td>
<td>0.06</td>
<td>0.17</td>
</tr>
<tr>
<td>5. I am a scientist</td>
<td>0.19</td>
<td>0.19</td>
</tr>
</tbody>
</table>
infit mean-square values between 0.6 and 1.4 for survey-based research. For an item to be retained in the forthcoming analyses, it had to fall within the recommended range across all three time-points. As noted above, two items from the Research Experience measure and three items from the Science Self-Efficacy measure were removed because they failed to meet this criterion. After removing the ill-fitting items, the resultant measures had infit mean-squared values between 0.73 and 1.32 and internal reliabilities greater than 0.90 (see Tables 2–4). Person-item maps for the Research Experience, Science Self-Efficacy, and Identity as Scientist measures are reported in online Supporting Information Figures 1–3, respectively. Overall, these figures illustrate that although the items for each measure are appropriate for most participants, they do not do a good job of assessing participants on the upper and lower ends of the distribution (i.e., participants who are either very high or very low in research experience, science self-efficacy, and identity as a scientist). As detailed later, this may bear on the generalizability of the findings.

Table 2

Psychometric characteristics of the research experience scale

<table>
<thead>
<tr>
<th>Item</th>
<th>Difficulty</th>
<th>Infit</th>
<th>MNSQ</th>
<th>1→2</th>
<th>2→3</th>
<th>3→4</th>
</tr>
</thead>
<tbody>
<tr>
<td>I took a leadership role in a scientific research team</td>
<td>0.92</td>
<td>1.25</td>
<td></td>
<td>−0.28</td>
<td>0.47</td>
<td>2.56</td>
</tr>
<tr>
<td>I had the opportunity to generate my own research question to answer</td>
<td>0.46</td>
<td>0.90</td>
<td></td>
<td>−0.73</td>
<td>0.02</td>
<td>2.10</td>
</tr>
<tr>
<td>I related my research results and explanations to the work of others</td>
<td>0.32</td>
<td>0.79</td>
<td></td>
<td>−0.87</td>
<td>−0.13</td>
<td>1.96</td>
</tr>
<tr>
<td>I worked on a research project in which I figured out what data to collect and how to collect it</td>
<td>0.12</td>
<td>1.03</td>
<td></td>
<td>−1.08</td>
<td>−0.33</td>
<td>1.76</td>
</tr>
<tr>
<td>I used scientific literature to guide a research project</td>
<td>−0.04</td>
<td>0.84</td>
<td></td>
<td>−1.23</td>
<td>−0.48</td>
<td>1.60</td>
</tr>
<tr>
<td>I reported my research results in an oral presentation or written report</td>
<td>−0.43</td>
<td>1.07</td>
<td></td>
<td>−1.62</td>
<td>−0.87</td>
<td>1.21</td>
</tr>
<tr>
<td>I learned technical science skills</td>
<td>−0.63</td>
<td>1.14</td>
<td></td>
<td>−1.82</td>
<td>−1.07</td>
<td>1.01</td>
</tr>
<tr>
<td>I learned scientific language and terminology</td>
<td>−0.73</td>
<td>0.96</td>
<td></td>
<td>−1.92</td>
<td>−1.18</td>
<td>0.91</td>
</tr>
</tbody>
</table>

Participants were randomly sampled across time-points, such that each of the three time-points is reflected in this analysis. MNSQ = Mean Square. Cronbach’s alpha for internal reliability = 0.96.

Table 3

Psychometric characteristics of the science self-efficacy scale

<table>
<thead>
<tr>
<th>Item</th>
<th>Difficulty</th>
<th>Infit</th>
<th>MNSQ</th>
<th>1→2</th>
<th>2→3</th>
<th>3→4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop theories</td>
<td>1.14</td>
<td>1.17</td>
<td></td>
<td>−1.92</td>
<td>1.03</td>
<td>4.30</td>
</tr>
<tr>
<td>Create explanations for the results of the study</td>
<td>0.38</td>
<td>0.74</td>
<td></td>
<td>−2.67</td>
<td>0.28</td>
<td>3.54</td>
</tr>
<tr>
<td>Generate a research question to answer</td>
<td>0.17</td>
<td>0.83</td>
<td></td>
<td>−2.89</td>
<td>0.06</td>
<td>3.32</td>
</tr>
<tr>
<td>Use scientific language and terminology</td>
<td>−0.20</td>
<td>1.06</td>
<td></td>
<td>−3.25</td>
<td>−0.30</td>
<td>2.96</td>
</tr>
<tr>
<td>Use technical science skills</td>
<td>−0.30</td>
<td>1.32</td>
<td></td>
<td>−3.35</td>
<td>−0.41</td>
<td>2.86</td>
</tr>
<tr>
<td>Relate results and explanations to the work of others</td>
<td>−0.33</td>
<td>0.83</td>
<td></td>
<td>−3.38</td>
<td>−0.43</td>
<td>2.83</td>
</tr>
<tr>
<td>Use scientific literature to guide research</td>
<td>−0.86</td>
<td>0.94</td>
<td></td>
<td>−3.91</td>
<td>−0.96</td>
<td>2.30</td>
</tr>
</tbody>
</table>

Participants were randomly sampled across time-points, such that each of the three time-points is reflected in this analysis. MNSQ = Mean Square. Cronbach’s alpha for internal reliability = 0.95.
Before conducting parametric analyses, it was necessary to ensure that each measure was assessed on the same metric across the three time-points. To accomplish this while avoiding violations of intra-person independence, participants were first randomly sampled across time-points such that each participant was in the data file just once, but all three time-points were equally represented (see Mallinson, 2011). A Rasch analysis was then carried out to derive item difficulties and Rasch-Andrich thresholds. The results of this analysis are reported in Tables 3, and 4. Next, the item difficulties and Rasch-Andrich thresholds were used as anchor values in a “stacked” data file that included all participants at all three time-points. Lastly, the stacked data file was Rasch-analyzed, and the resultant logits were exported to SPSS and Mplus for parametric analyses. This process was carried out separately for each of the three measures.

**Preliminary Analyses**

Table 5 presents the correlation matrix for research experience, efficacy, and identity across all three time-points. All correlations were significant at the .001 level. Correlations within a given construct over time ranged from 0.47–0.61 for research experience, 0.47–0.57 for science self-identity, and 0.47–0.67 for science self-efficacy. Participants were randomly sampled across time-points, such that each of the three time-points is reflected in this analysis. MNSQ = Mean Square. Cronbach’s alpha for internal reliability = 0.96.

<table>
<thead>
<tr>
<th>Item</th>
<th>Difficulty</th>
<th>Infit</th>
<th>MNSQ</th>
<th>1→2</th>
<th>2→3</th>
<th>3→4</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have a strong sense of belonging in the community of scientists</td>
<td>0.93</td>
<td>1.09</td>
<td>-1.69</td>
<td>0.33</td>
<td>4.15</td>
<td></td>
</tr>
<tr>
<td>Being a scientist is an important reflection of who I am</td>
<td>0.18</td>
<td>0.73</td>
<td>-2.44</td>
<td>-0.42</td>
<td>3.40</td>
<td></td>
</tr>
<tr>
<td>I am a scientist</td>
<td>0.01</td>
<td>1.19</td>
<td>-2.61</td>
<td>-0.59</td>
<td>3.23</td>
<td></td>
</tr>
<tr>
<td>In general, being a scientist is an important part of my self-image</td>
<td>-0.32</td>
<td>0.90</td>
<td>-2.94</td>
<td>-0.92</td>
<td>2.90</td>
<td></td>
</tr>
<tr>
<td>I feel like I belong in the field of science</td>
<td>-0.80</td>
<td>0.99</td>
<td>-3.42</td>
<td>-1.40</td>
<td>2.42</td>
<td></td>
</tr>
</tbody>
</table>

Correlation matrix for study variables at Time 1, Time 2, and Time 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 Research Experience</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2 Research Experience</td>
<td>0.60</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3 Research Experience</td>
<td>0.47</td>
<td>0.61</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1 Self-Efficacy</td>
<td>0.56</td>
<td>0.44</td>
<td>0.38</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2 Self-Efficacy</td>
<td>0.46</td>
<td>0.66</td>
<td>0.46</td>
<td>0.56</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3 Self-Efficacy</td>
<td>0.43</td>
<td>0.48</td>
<td>0.67</td>
<td>0.47</td>
<td>0.57</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1 Identity</td>
<td>0.42</td>
<td>0.26</td>
<td>0.25</td>
<td>0.40</td>
<td>0.35</td>
<td>0.31</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2 Identity</td>
<td>0.36</td>
<td>0.41</td>
<td>0.31</td>
<td>0.29</td>
<td>0.42</td>
<td>0.30</td>
<td>0.56</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>T3 Identity</td>
<td>0.32</td>
<td>0.30</td>
<td>0.43</td>
<td>0.21</td>
<td>0.36</td>
<td>0.47</td>
<td>0.42</td>
<td>0.51</td>
<td>—</td>
</tr>
</tbody>
</table>

N = 251. Responses on each scale could range from 1 to 4. All correlations are significant at the 0.001 level.
efficacy, and 0.42–0.56 for identity as a scientist. Thus, each construct had at least moderate rank-order stability over time (Cole & Maxwell, 2003).

To test for change over time and main effects of cohort, ethnicity, and gender, study variables were subjected to a mixed repeated-measures analyses of variance. Results indicated that mean levels of research experience increased over time, Wilks’ $\Lambda = 0.77, F(2, 241) = 38.33, p < 0.001, \eta^2_p = 0.24$. There was also a main effect of ethnicity, which illustrated that participants from underrepresented ethnic minority groups obtained more research experience over the course of the study than did other participants, $F(1, 242) = 4.95, p = 0.03, \eta^2_p = 0.02$. With respect to science self-efficacy, mean levels increased over time, Wilks’ $\Lambda = 0.76, F(2, 241) = 36.27, p < 0.001, \eta^2_p = 0.23$, but main effects of cohort, ethnicity, and gender were not obtained. Similarly, mean levels of identity as a scientist increased over time, Wilks’ $\Lambda = 0.91, F(2, 241) = 12.48, p < 0.001, \eta^2_p = 0.10$, but main effects of cohort, ethnicity, and gender were not obtained.

To test for potential attrition effects, two sets of analyses were conducted. First, a MANOVA was carried out on the Time 1 data to examine whether mean levels of research experience, efficacy, and identity differed for participants who persisted in the study versus those who did not. The MANOVA was non-significant, Wilks’ $\Lambda = 0.99, F(3, 806) = 0.86, p = 0.46$. Therefore, mean levels of research experience, efficacy, and identity at the outset of the study did not appear to be associated with later attrition. In a second set of analyses, separate $2 \times 2$ chi-square tests of independence assessed whether participants who persisted in the study differed from those who did not in terms of their ethnic background and gender. The first chi-square indicated that participants of differing ethnic backgrounds had similar attrition rates, $\chi^2 (1, N = 806) = 2.69, p = 0.11$. The second chi-square indicated that women were more likely than men to complete the full study, $\chi^2 (1, N = 806) = 5.90, p = 0.02$. Specifically, 44% of women participated at each time-point versus 35% of men.

**Longitudinal Associations Among Research Experience, Self-Efficacy, and Identity**

**Overview of Analyses.** The main goal of the current study was to examine the longitudinal associations among research experience, science self-efficacy, and identity as a scientist. Specifically, we expected that T2 science self-efficacy would mediate the association between T1 research experience and T3 identity as a scientist (see Figure 1). This hypothesis was tested with a three-wave cross-lagged panel model. Cole and Maxwell’s (2003) guidelines for testing mediation with longitudinal data informed the model testing process (see also Maxwell & Cole, 2007). The model was composed of Rasch-transformed manifest variables (measured in logit units), and analyses were carried out with Mplus version 6.1 using maximum likelihood estimation.

**Model Specification and Mediation Analyses.** The cross-lagged model included autoregressive paths as well as within-time correlations (see Cole & Maxwell, 2003). However, the paths of primary interest were cross-lagged associations among research experience, science self-efficacy, and identity as a scientist, which provided insight into whether these variables predicted one another over time. Given the large number of cross-lagged paths that could be estimated, we began by specifying a model that included only downward paths. These paths were estimated first because their directionality was consistent with hypotheses. We then examined the modification indices to gauge whether any upward paths were missing from the model. Improvement in model fit was assessed through nested model comparisons, which were carried out through chi-square difference tests (see Kline, 2005). If a given chi-square difference test is significant, the model with more paths fits significantly better than the model with fewer paths.

The first model that was specified included the hypothesized downward paths running from T1 to T2 constructs and from T2 to T3 constructs. The fit of this model was fair, but the
Modification indices suggested that fit would be improved with the inclusion of two upward paths: (1) T1 efficacy → T2 research experience and (2) T1 identity → T2 efficacy. Adding these paths led to a significant improvement in model fit, \( \Delta \chi^2(2, N = 251) = 16.06, p < 0.001 \). In this modified model, the path from T1 efficacy → T2 identity was non-significant, and removing it from the model did not lead to a decrement in model fit, \( \Delta \chi^2(2, N = 251) = 1.96, p = 0.16 \). The fit of the resultant model was acceptable, \( \chi^2(16, N = 251) = 36.12, p = 0.003; \text{CFI} = 0.98, \text{SRMR} = 0.05, \text{RMSEA} = 0.07 \) (90% CI: 0.04, 0.10); it was therefore retained as the final model (see Figure 2).

The next analytic step was a test of the hypothesized mediational association involving research experience, science self-efficacy, and identity as a scientist. These analyses focused on two significant downward paths: T1 research experience → T2 efficacy (\( \beta = 0.14, p = 0.02 \)) and T2 efficacy → T3 identity (\( \beta = 0.17, p = 0.004 \)). First, science self-efficacy was removed from the model, and the direct path from T1 research experience to T3 identity was estimated. This path was significant (\( \beta = 0.12, p = 0.03 \)). Next, the direct path from T1 research experience to T3 identity was estimated in the full model (see Figure 2), which included science self-efficacy. In this model, however, the direct path was non-significant (\( \beta = 0.06, p = 0.32 \)). According to Baron and Kenny (1986), this pattern illustrates that science self-efficacy functions as a mediator. Additional support for this conclusion was obtained in the test of the indirect effect of T1 research experience on T3 identity as a scientist via T2 science self-efficacy (see MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002), which was marginally significant (\( \beta = 0.03, p = 0.07 \)). Collectively, these findings indicate that, as hypothesized, research experience at Time 1 predicts heightened identity as a scientist 2 years later at Time 3, and that this association is mediated by science self-efficacy at Time 2.

**Test of Competing Models.** In an effort to rule out competing hypotheses, we tested two additional models. The first was a model in which the roles of science self-efficacy and research experience were reversed. That is, T1 science self-efficacy was specified as a predictor of T2 research experience, which was in turn specified as a predictor of T3 identity as a scientist.

![Figure 2](image-url)  
*Figure 2.* Cross-lagged model with research experience, science self-efficacy, and identity as a scientist. All coefficients are standardized. Only paths significant at the .05 level are depicted. Error terms within-time correlated errors are not pictured. Bold arrows highlight the hypothesized mediational associations between T1 research experience, T2 science self-efficacy, and T3 identity as a scientist.

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Findings did not yield support for this model. First, model fit was mediocre, $\chi^2(19, N = 251) = 70.81, p < 0.001; \text{CFI} = 0.94, \text{SRMR} = 0.10, \text{RMSEA} = 0.11$ (90% CI: 0.08, 0.13). Moreover, the path from T2 efficacy to T3 identity was non-significant, and the indirect effect of T1 efficacy on T3 identity via T2 research experience was non-significant as well. The second competing model we tested was one in which the hypothesized direction of mediation was reversed. Specifically, this model included upward paths from T1 to T2 constructs and from T2 to T3 constructs. Support for this model would suggest that identity as a scientist predicts science self-efficacy, which in turn predicts greater involvement in research. However, the data did not support the competing model. First, model fit was mediocre, $\chi^2(17, N = 251) = 56.48, p < 0.001; \text{CFI} = 0.95, \text{SRMR} = 0.09, \text{RMSEA} = 0.10$ (90% CI: 0.07, 0.13). More importantly, the indirect effect of T1 identity on T3 research experience via T2 efficacy was non-significant, which indicates that there was not a mediation effect. Collectively, these two tests of competing models provide further evidence in favor of the directional flow of mediation that was hypothesized in the current study.

**Ethnicity and Gender Moderation.** In a final set of analyses, follow-up tests examined whether participant ethnicity or gender moderated paths in the model depicted in Figure 2. Specifically, multiple-group path analysis was used to compare a model in which paths were allowed to vary based on ethnicity or gender to a model in which paths were not allowed to vary. According to Kline (2005), if constraining a particular path to equality leads to a significant decrement in model fit, it can be concluded that group membership moderates that association. The multiple-group analyses focused on the two paths that were most central to predictions advanced in the current study: (1) T1 research experience → T2 efficacy and (2) T2 efficacy → T3 identity. When these paths were constrained to equality for women and men, model fit did not significantly differ from a model in which these paths were allowed to vary, $\Delta\chi^2(2, N = 251) = 2.69, p = 0.26$. Furthermore, the model explained similar amounts of variance in women’s and men’s T3 identity as a scientist ($R^2$ women = 0.28; $R^2$ men = 0.22).

To examine whether ethnicity functioned as a moderator, participants were divided into two groups on the basis of whether their ethnic group was underrepresented (i.e., African American, Latino/a, Native American/Indigenous) or overrepresented (i.e., Asian American and European American) in science fields. Similar to the analysis for gender, the fit of the model in which the paths were allowed to vary by ethnicity did not differ from a model in which these paths were constrained to equality, $\Delta\chi^2(2, N = 251) = 0.50, p = 0.78$. However, it bears noting that the model explained less variance in T3 identity as a scientist for members of underrepresented ethnic groups than it did for members of overrepresented ethnic groups ($R^2$ underrepresented = 0.19; $R^2$ overrepresented = 0.46).

**Discussion**

The current study sought to shed light on the processes through which undergraduates come to view “scientist” as a core component of their identity. In particular, we were interested in the longitudinal associations among research experience, science self-efficacy, and identity as a scientist. As expected, participants’ involvement in research predicted the extent to which they identified as scientists nearly 2 years later, and science self-efficacy mediated this association. These findings underscore the long term benefits of research involvement for undergraduates in the science pipeline. Moreover, the results of the present study provide initial support for the contention that science self-efficacy mediates the association between research involvement and positive academic outcomes (see Sadler et al., 2010). Below, we elaborate on these findings and conclude with several limitations and corresponding directions for future research.
Test of the Hypothesized Mediation Model

Associations Between Research Experience and Science Self-Efficacy

The present study joins a growing body of research indicating that involvement in research can have positive implications for students’ science self-efficacy (e.g., Adedokun et al., 2013; Chemers et al., 2011; Hunter et al., 2006; Seymour et al., 2004). Relative to past research, however, the present study has the added benefit of being able to test the directionality of the association between research experience and science self-efficacy. We hypothesized that research experience would lead to greater science self-efficacy, but the reverse pathway was also tested. Our findings demonstrated that these two factors were reciprocally related during the first half of the study. Specifically, greater research experience at the outset of the study was associated with gains in efficacy at Time 2 (hypothesized), but it was also the case that greater efficacy at the outset of the study was associated with gains in research experience at Time 2 (not hypothesized). In contrast, only the hypothesized research experience → efficacy path was significant in the latter half of the study.

Although it was not hypothesized, the association between science self-efficacy at Time 1 and research experience at Time 2 is not entirely surprising. Prominent models of academic motivation and career aspirations such as expectancy-value theory and social-cognitive career theory indicate that self-efficacy contributes to academic choices such as involvement in a research lab (Brown et al., 1996; Eccles & Wigfield, 2002; Lent & Brown, 2006). Notably, both perspectives also postulate a feedback loop whereby self-efficacy promotes academic choices, which in turn influence future self-efficacy (see also Graham et al., 2013). This pattern is consistent with the reciprocal association between research experience and science self-efficacy that was obtained during the first half of the present study.

Associations Between Science Self-Efficacy and Identity as a Scientist

The present study also aimed to shed light on the association between science self-efficacy and identity as a scientist. The connection between efficacy and identity has been considered in several past qualitative studies (e.g., Margolis et al., 2000), but relatively few quantitative studies. The current study builds on this work by using quantitative, longitudinal data to examine the directionality of the association between efficacy and identity. As hypothesized, greater levels of science self-efficacy at Time 2 predicted heightened identity as a scientist at Time 3. This implies that students’ level of self-efficacy in a particular academic domain can influence the extent to which that domain is incorporated into their identity. Such a pattern is consistent with the finding that undergraduates associate increases in their science self-efficacy with feelings of becoming a scientist (Hunter et al., 2006).

Whereas the directionality of the association between efficacy and identity was consistent with hypotheses from Time 2 to Time 3, the reverse association was obtained from Time 1 to Time 2. This pattern is consistent with a cyclical model of science persistence that Graham et al. (2013) recently proposed in which confidence in science promotes identification with science, which then further enhances confidence.

Given the relative novelty of these findings, it is important that they be replicated with both longitudinal and experimental research in the future. However, as the first longitudinal data considering the associations among research experience, efficacy, and identity, the results of the present study constitute an important advance in understanding how these constructs relate to one another over time. Moreover, the insight this study provides into the link between efficacy and identity is meaningful because it was obtained in a sample that was largely composed of women and underrepresented ethnic minority students. Members of these groups often face barriers in
coming to identify with science (e.g., London, Rosenthal, Levy, & Lobel 2011; Syed, 2010), which makes it especially important to pinpoint constructs that contribute to identity as a scientist within these students.

**Science Self-Efficacy as a Mediator**

In a recent review, Sadler et al. (2010) suggested that self-efficacy may be a mediator that helps to explain why research involvement tends to have a positive impact on academic outcomes. The results of the current study indicate that this is indeed the case with respect to the association between research experience and identity as a scientist. Specifically, science self-efficacy functioned as a mediator and, furthermore, the data did not support a model in which the hypothesized direction of mediation was reversed. Collectively, these findings provide preliminary evidence of a causal flow that begins with research experience, runs through science self-efficacy, and concludes at identity as a scientist.

Beyond the implications outlined above, science self-efficacy’s role as a mediator is also informative from an applied standpoint. Specifically, the results of the present study raise the possibility that involvement in research may not be uniformly beneficial; rather, it appears to be especially important to involve undergraduates in research that has the potential to increase their science self-efficacy. This notion dovetails with the increasing emphasis that science educators have placed on authentic research experience and active learning within science classrooms (e.g., Chinn & Malhotra, 2002; Handelsman et al., 2004, 2005; Hunter et al., 2006). For example, Chinn and Malhotra (2002) note that the assignments students complete in science classes often bear little resemblance to the work that occurs within the actual practice of science. Similarly, Handelsman et al. (2004) argue that science teaching at the undergraduate level needs to deemphasize lectures and “cookbook” lab experiments and instead focus on providing students with authentic, inquiry-based research opportunities that can enhance their science self-efficacy. We echo this sentiment and add that mentors and advisors should carefully consider whether their undergraduate research assistants are engaged in tasks that have the potential to bolster their science self-efficacy. Constructivist approaches to education (e.g., Vygotsky, 1978) suggest that this can be accomplished by tailoring tasks to students’ ability level and by providing them with scaffolding from more experienced members of the research laboratory. In support of this point, research illustrates that both authentic research experience and appropriate scaffolding facilitate doctoral students’ transition into practicing scientists (Bhattacharyya & Bodner, 2014).

A related applied implication pertains to the timing of students’ research involvement. Graham et al. (2013) recently argued that it is essential for students to participate in research early in their academic trajectories, which contrasts with existing norms at many universities. The results of the current study support this argument by suggesting that the association between research experience, efficacy, and identity may unfold over the course of months or potentially years. Hence, it is possible that promoting early research involvement would lead to a greater proportion of undergraduates viewing themselves as scientists well before graduating, which should in turn be associated with greater overall retention in the science pipeline (see Estrada et al., 2010).

**Moderation on the Basis of Ethnicity and Gender**

Women and members of underrepresented ethnic groups face particular challenges in coming to identify with science (Aschbacher et al., 2010; Carlone & Johnson, 2007; Syed, 2010). As a result, universities and government funding agencies have developed outreach programs and academic interventions that cater to these students. Little is known, however, about whether the effectiveness of academic outreach and interventions varies on the basis of student background.
characteristics such as ethnicity or gender. The present study investigated this possibility by conducting exploratory analyses that tested for ethnic and gender differences in the hypothesized model.

Results illustrated that the associations between research experience, science self-efficacy, and identity as a scientist did not significantly differ as a function of ethnicity or gender. However, it merits noting that the model explained less variance in identity as a scientist for participants who identified as African American, Latino, or Native American (19%) than it did for participants who identified as Asian American or European American (46%). Thus, it may be that constructs in addition to those examined in the current study are central to understanding how identity as a scientist develops for students from underrepresented ethnic groups. For instance, factors such as academic preparation during high school and emotional support from parents, peers, and teachers have been linked to academic outcomes for students from underrepresented ethnic groups (Azmitia, Cooper, & Brown, 2009; Chang, Sharkness, Hurtado, & Newman, 2014). Therefore, perhaps considering these constructs in addition to research experience and science self-efficacy would result in a greater amount of variance explained in identity as a scientist for students from diverse backgrounds.

Limitations and Future Directions

The present study has several limitations, which we now highlight along with corresponding directions for future research. First, from a psychometric standpoint, the measures of research experience, science self-efficacy, and identity as a scientist were not especially effective in assessing participants who were at the upper and lower ends of the distribution for each scale. Thus, the findings of the current study may apply most directly to participants who tend to be closer to the mean on these constructs. Future research that utilizes these scales should include a broader range of items; specifically, it would be valuable to include some items that are easier for participants to endorse and some that are more difficult for participants to endorse. Doing so would allow researchers to more effectively assess undergraduates with a wide range of abilities and experiences.

Another limitation of the current study is that it does not provide definitive information about the causal link between research experience, science self-efficacy, and identity as a scientist. The longitudinal design that was used sheds more light on causality than does research conducted at one time-point, but these claims would be strengthened by experimental research that manipulates students’ level of research involvement or science self-efficacy.

It is also important to examine whether the results of the present study can be replicated after controlling for variables that covary with research experience such as mentoring and peer connectedness. To our knowledge, these factors have not been simultaneously examined in prior work. However, cross-sectional research indicates that mentoring and research experience independently predict science self-efficacy (Chemers et al., 2011), and longitudinal research suggests that research experience has a stronger effect on persistence in science than does mentoring (Schultz et al., 2011). Less clear is whether peer connectedness, which is often fostered within a lab setting, helps to account for the connection between research experience and identity as a scientist. That is, perhaps research experience provides students with opportunities to develop close social ties with other motivated science students (e.g., Stake & Nickens, 2005), which in turn leads them to identify more strongly with science. This is important to clarify given that recent research has underscored the important role peer connectedness plays in students’ pursuit of science careers (e.g., Cohen & Garcia, 2008; Robnett, 2013; Robnett & Leaper, 2013).

In evaluating the results of the current study, both attrition and generalizability should be taken into account. First, with respect to attrition, only about 40% of the original sample
participated at all time-points. Moreover, attrition was more common in men than in women. Although analyses indicated that attrition was not associated with significant differences in research experience, science self-efficacy, or identity as a scientist at Time 1, it is possible that students who persisted differed from students who did not along dimensions that were not examined in the current study. If this were the case, it would limit the generalizability of the findings. Relatedly, participants in the present study all attended the SACNAS research conference, which implies that they may be more academically motivated and/or capable than many undergraduates in science majors. Therefore, it is possible that the patterns observed in the current study are mainly generalizable to high-performing science students. A final point related to generalizability pertains to field of study. Specifically, the current research included participants from a variety of science fields, and sample size limitations precluded an assessment of whether field of study moderated the findings. Given that the academic climate in specific science fields does appear to vary (e.g., Sonnert, Fox, & Adkins, 2007), future research should examine whether the results of the current study differ as a function of students’ area of study.

Another direction for future research pertains to intersectionality (Hill Collins, 1986). It seems plausible that intersecting identities contour students’ experiences in science fields. For example, a woman who is African American likely faces challenges in her pursuit of a science degree that differ from the challenges faced by a woman who is European American. Although several qualitative studies provide rich insight into the experiences of individuals who identify with multiple marginalized groups (e.g., Johnson, 2007; Wilson & Kittleson, 2013), this work would be bolstered by large-scale quantitative and mixed-methods studies that make targeted comparisons between participants who differ on the basis of crosscutting social identities. Indeed, research conducted with African American youth suggests that an intersectionality framework may help to explain variation in academic outcomes among college and graduate students (e.g., Wood, Kurtz-Costes, & Copping, 2011).

A final limitation of the present study is its reliance on self-report measures. The results would be enriched with reports from sources such as parents, peers, or mentors. In addition, the present study did not include a behavioral outcome measure. It is our hope that enhancing the extent to which students identify with science will have positive implications for their retention in the science pipeline, but our findings do not directly speak to this possibility. However, we are encouraged by research that has linked identity as a scientist to behavioral outcomes. For instance, Estrada et al. (2010) found that undergraduates who were high in identity as a scientist were especially likely to apply to graduate school in a science-related field. Thus, it seems reasonable to expect that students who are high in identity as a scientist are more likely than other students to pursue advanced degrees and careers in the sciences.

Concluding Remarks

In sum, the results of the present study build on past research by examining the longitudinal associations among research experience, science self-efficacy, and identity as a scientist. As hypothesized, science self-efficacy mediated the association between research experience and subsequent levels of identity as a scientist. These findings both complement and clarify past research, particularly with respect to the directionality of the paths between the constructs in the model. Also, the results of the present study highlight the importance of involving undergraduates in research that has the potential to enhance their science self-efficacy. Exploratory analyses demonstrated that paths in the model were not moderated by participants’ ethnicity or gender. However, the model accounted for more variance in identity as a scientist for students from overrepresented ethnic background than for students from underrepresented ethnic backgrounds. Hence, future research should aim
to identify constructs that work in concert with research experience and science-self efficacy to shape identity as a scientist for underrepresented students.

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Endnotes

1 Although SACNAS caters to individuals who identify as Hispanic, Chicano/a, and Native American, their annual conference is open to students of all ethnic backgrounds. For this reason, our sample is composed of students from a variety of ethnic groups.

2 Percentages do not sum to 100 because participants were permitted to identify with multiple ethnic groups. Participants who identified with both an under- and over-represented group (e.g., Latino and European American) were classified as underrepresented in the multiple-group comparisons.

3 The possibility of differential item functioning across time-points was also examined in this step. Results revealed a single item from the research experience measure that functioned differently at Time 1 than it did at Time 2 and Time 3. However, because this item was only problematic at a single time-point and was otherwise psychometrically sound, it was retained in the parametric analyses.

References


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