Journal of Women and Minorities in Science and Engineering 18(3), 273–293 (2012)

PORTRAITS OF SCIENCE SELF-EFFICACY: FOUR UNDERGRADUATE WOMEN IN A SUMMER RESEARCH EXPERIENCE

Shari L. Britner,[1,]* Brian Williams,[2] John L. Pecore,[3] Phillip Gagne,[2] Melissa K. Demetrikopoulos,[4] Rob Poh,[5] Laura L. Carruth,[5] Chris T. Goode,[6] Robert L. DeHaan,[7] & Kyle J. Frantz[5]

[1]*Department of Teacher Education, Bradley University, Peoria, Illinois 61625, USA*

[2]*College of Education, Georgia State University, Atlanta, Georgia 30302-3980, USA*

[3]*School of Education, University of West Florida, Pensacola, FL. 32514, USA*

[4]*Division of Program Development & Assessment, Institute for Biomedical Philosophy, Dunedin, Florida 34697, USA*

[5]*Neuroscience Institute, Georgia State University, Atlanta, Georgia 30302-5030, USA*

[6]*Department of Psychology, Georgia State University, Atlanta, Georgia 30302-5010, USA*

[7]*Professor of Cell Biology Emeritus, Emory University, Atlanta, Georgia 30322, USA*

* Address all correspondence to: Shari L. Britner, E-mail: sbritner@bradley.edu

To strengthen the US scientific workforce, we aim to recruit and retain talented students in science, technology, engineering, and math (STEM) fields, to enhance success among students from groups underrepresented in STEM fields, and to diversify the scientific workforce to mirror the US population. Given that opportunities for authentic research may support STEM advancement, we seek to maximize the number of students involved in research. Our Behavioral Research Advancements in Neuroscience (BRAIN) research program tests the hypothesis that a team-based collaborative-learning model not only provides research opportunities for more students, but also produces outcomes at least as positive as a traditional one-on-one apprenticeship model. We examined scientific research self-efficacy as a critical construct for measuring student outcomes and predicting student progress toward STEM careers. Here we provide descriptive portraits of four women who participated in BRAIN, integrating quantitative survey data with analysis of pre- and post- semistructured interviews. Although selected for different self-efficacy trajectories in the quantitative surveys, all four women described increased self-efficacy in interviews and emphasized mastery experiences as a source of self-efficacy. Two women illustrate one general outcome from the program: women overcame initially lower scientific research self-efficacy, matching self-efficacy among men by mid-program. The overarching study suggests that both team-based research and apprenticeships can raise scientific research self-efficacy, which predicts STEM career success. Therefore, this collaborative model provides a structure for authentic research at institutions that may lack available mentors, and yet aim to improve opportunities for diverse undergraduate groups to pursue STEM careers.

KEY WORDS: *minorities, women, neuroscience, African American, qualitative, mixed-methods, motivation, mentoring, collaborate*

ISSN 1072-8325/12/$35.00

1. INTRODUCTION

In past decades, the aim of introductory science and math courses in college was to "weed out" undergraduate students, and sustain only those judged most likely to progress toward science- and math-related careers (Seymour and Hewitt, 1997; Treisman, 1992). More recently, declining interest and motivation in science and math among first-year college students have changed the role of these introductory courses to enhance retention. These changes, also driven by science education research on ways to improve teaching and learning techniques (Halme *et al.*, 2006; Peterson and Miller, 2004), frequently reduce emphasis on didactic teaching and increase emphasis on inquiry-oriented and student-centered learning (DeHaan, 2005; Fencl and Scheel, 2005; NRC, 2003). Of particular focus are mechanisms to retain students from academically underrepresented groups, such as racial or ethnic minorities and women, for whom exit rates from undergraduate science majors are proportionately greater than for other groups (Dirks and Cunningham, 2006; Seymour and Hewitt, 1997). The Center for Behavioral Neuroscience, an Atlanta-based National Science Foundation (NSF) Science and Technology Center (STC), aims to recruit and train the next generation of neuroscientists, with emphasis on success among trainees from underrepresented groups (Center for Behavioral Neuroscience, 1999). Some faculty members in the center have thus adopted effective approaches to teaching, learning, recruitment, and retention of talented undergraduate students in pathways toward research and teaching careers.

Through a meta-analysis, Seymour *et al.* (2004) concluded that laboratory research programs generate positive outcomes for undergraduate participants. Students demonstrate broadened and matured views on the nature of science (Ryder *et al.*, 1999) and report improved self-efficacy with research skills after research experience (Kardash, 2000). Students also cite enhanced understanding of the research process and how to approach scientific problems, as well as readiness for more demanding research, as outcomes from research experiences (Lopatto, 2007).

Self-efficacy is defined as people's judgments of their capabilities to produce designated levels of performance (Bandura, 1986). Self-efficacy in science, therefore, is one's belief that one has the ability to succeed in the particular tasks necessary for careers related to science, and has proven to be a particularly useful construct in both supporting and predicting students' continuation in science-related fields. Given that our summer program focuses on research in various subfields of neuroscience, we focused further on students' beliefs in their abilities to succeed in scientific research. This article presents a case study approach to exploring the factors related to the scientific research self-efficacy development of four women from a larger ongoing study. In the overarching study, two models of undergraduate summer research experience are compared, not only in terms of effects on students' scientific research self-efficacy, but also on their leadership/teamwork self-efficacy, science identity, science and neuroscience anxiety, and long-term career progress in science- and math-related careers, among additional factors. A portion of this dataset has been reported elsewhere (Goode *et al.*, in press).

2. THEORETICAL FRAMEWORK

Self-efficacy is the central construct in Bandura's (1986, 1997) social cognitive theory, according to which people are more likely to perform tasks they believe they are capable of accomplishing and less likely to engage in tasks about which they feel less competent. Individuals' perceptions of their competencies are powerful motivators that affect the choices they make, the effort and persistence they put forth, and the resilience they show in overcoming obstacles. Self-efficacy beliefs also play a mediational role in that they serve as filters between prior achievements or abilities and subsequent behavior. For example, students who interpret the results of their test scores favorably may use that interpretation to fuel their effort to study hard so as to perform well on subsequent exams.

Bandura (1997) theorized that students form their self-efficacy beliefs by interpreting information from four sources, which can be described as follows. The most influential is the interpretation of previous performance, or *mastery experience*. Students engage in tasks and activities, interpret the results of their actions, use these interpretations to develop beliefs about their capability to engage in subsequent tasks or activities, and make decisions based on the beliefs created. Experiences interpreted as successful generally raise confidence; experiences interpreted as unsuccessful generally lower it.

The second source of self-efficacy information is the vicarious experience gained by observing others as they perform tasks. By observing the successes and failures of others, people gather information that contributes to their judgments about their own capabilities. This kind of modeling has the greatest influence when the models are perceived to be similar to the observer and in situations in which the observer has little personal experience.

Social or verbal persuasions—messages from others about one's ability to accomplish a task—are hypothesized to exert the most positive influence on those who already have a strong sense of self-efficacy. Social messages can encourage people to exert the extra effort to succeed, resulting in further development of skills and personal efficacy. Persuasions can also work to undermine efficacy beliefs when used to convince people that they lack capabilities. Derogatory statements about one's competence in a particular area are believed to have the most detrimental effect on the confidence judgments of those who already lack confidence in their capabilities.

People look to their physiological and emotional states as a fourth source of information about their capabilities. Powerful emotional arousal, such as anxiety, can effectively alter individuals' beliefs about their capabilities. For example, people may view a state of arousal as an energizing factor that can contribute to a successful performance; alternatively, they may view arousal as completely disabling. The intensity of the emotional arousal is also a factor in how the individual interprets this information.

Ultimately, individuals construct their self-efficacy beliefs through the interpretation and integration of information from these four sources—mastery experiences, vicarious experiences, social persuasions, and physiological and affective states. The strength of the contribution made by each source varies depending on the domain in question and on the cognitive processing strategies of the individual. Of significant note, these sources frequently operate congruently, e.g., individuals often experience their own success or failure while at the same time observing others engaging in the same activity. It is also possible, if not likely, for an individual to receive feedback that constitutes social persuasion and to experience physiological and affective states during and after an experience, all of which will be integrated into future self-efficacy beliefs. The cognitive processing required to integrate information from multiple sources plays a major role in determining an individual's self-efficacy beliefs.

Researchers of self-efficacy have agreed that quantitative studies need to be complemented by qualitative inquiry to provide the rich descriptions that are often available through narratives (Pajares, 1996, 1997; Schunk, 1991). For example, Zeldin and Pajares (2000) employed qualitative methodology to discover the role played by self-efficacy beliefs in the career and academic paths of women in science, technology, engineering, and mathematics (STEM) careers. They developed an interview protocol that was based on the theoretical sources of self-efficacy, allowed participants to explore the ways in which they felt their confidence was developed, but avoided leading them to speak specifically about any one source of self-efficacy with greater frequency than another. Interestingly, the findings of Zeldin and Pajares (2000) ran counter to previous research on self-efficacy, with vicarious experiences and social persuasions being the sources of self-efficacy most described by these women. Subsequently, Zeldin *et al.* (2008) replicated the study with men in STEM careers using the qualitative protocol described above. In contrast to the women, men described primarily mastery experiences as contributing to the development of confidence and perseverance in their science careers.

As all of the participants in the previous two studies were Caucasian, the study has been replicated a third time with African American scientists, both men and women (Britner, in preparation). Among the African American scientists, the distinction among the sources of self-efficacy they identified as being the most significant proved not to fall along gender lines but rather the type of undergraduate institution they attended. Most of the scientists who had attended historically black colleges and universities (HBCUs) emphasized the effects of vicarious experiences and social persuasions, whereas those who had completed their undergraduate education at other types of institutions primarily emphasized mastery experiences as the primary sources of self-efficacy information.

As it is a long-term goal of the Behavioral Research Advancements in Neuroscience (BRAIN) program to increase diversity in the US scientific workforce, we are interested in listening to the voices of individual participants with diverse backgrounds and experiences in the program. Here we use narratives provided in two semistructured interviews to take a closer look at the experience of four women in our undergraduate neuroscience research program. We supplement their narratives with quantitative data from a series of online surveys required of all program participants before the program began, in the middle, and at the end (pre-, mid-, and post-program surveys). The surveys included several instruments: scientific research self-efficacy, leadership/teamwork self-efficacy, science identity, science anxiety, neuroscience anxiety, and commitment to science. In fact, we used the trajectory of change in scientific research self-efficacy to identify the four individuals of focus in this report; we aimed to choose cases with differing trajectories of self-efficacy, including rising, falling, or steady self-efficacy.

Research Question: How do students with differing trajectories of self-efficacy describe their self-efficacy and the sources of their self-efficacy?

3. METHODS

3.1 Program Description

A long-term goal of our program is recruitment and retention of talented individuals in pathways toward STEM careers, with a focus on students from groups currently underrepresented in the sciences, including racial/ethnic minorities, students with documented disabilities, women (underrepresented in some areas of study and at higher levels), and those from disadvantaged socioeconomic or educational backgrounds. Thus, we designed a 10-week summer research program for undergraduate students, known as *Behavioral Research Advancements in Neuroscience* (BRAIN). To test whether more students could be provided with beneficial research experience in a team-based format compared with a traditional one-on-one apprenticeship, we included both a collaborative-learning model (CLM) and an apprenticeship model (AM) in the program design. Each model was designed to provide research experience in the field of behavioral neuroscience.

3.1.1 Basic Neuroscience Curriculum

The content focus of our undergraduate research program was behavioral neuroscience. For the first week of the program all participants explored basic neuroscience concepts. Instructors (faculty members, postdoctoral fellows, and graduate students) led participants through explorations of cellular/molecular neuroscience and systems/behavioral neuroscience, combining lectures and laboratory-based experiences designed to increase both specific content knowledge and critical thinking skills. Instructors and assistants were trained in the curriculum content and teaching approaches in order to maintain treatment fidelity across cohorts.

The immediate research goal of this project has been to compare two models of an undergraduate summer neuroscience research experience in terms of the models' effects on students' self-efficacy and mastery of science content. Ultimately, the project will measure long-term progress in science- and math-related careers. Thus, students were randomly assigned to one of the two program formats described below. For nine weeks after the orientation course, participants worked in their research environments for 35 hr/week, coming together weekly for a 3- or 4-hour professional development workshop.

3.1.2 The Collaborative-Learning Model (CLM)

During weeks 2-6 of the program, the CLM participants engaged in a semistructured neurobiology and behavior research curriculum designed using red swamp crayfish (*Procambarus clarkii*) as the animal model. Each week began with instructor-led demonstrations of research techniques common to behavioral neuroscience, including anatomy and behavior, pharmacology, and molecular biology. Participants practiced techniques, collected data, and conducted analyses, graphing, and interpretation to learn basic scientific research skills. Instructors offered guidance and management, while encouraging creativity and originality in thinking about subsequent team projects. During weeks 7–10, self-identified collaborative teams of students generated an experimental question of their choice, and then designed and conducted their own pilot investigations. In this phase of the program, CLM instructor/mentors reviewed ideas, read protocols, provided guidance, and assisted with data collection and analysis, as needed. The program culminated with submission of a research minigrant proposal submitted as a team-written document, based on pilot data, and presented in poster format at a research symposium.

3.1.3 The Apprenticeship Model (AM)

Each AM participant engaged in ongoing research in an active neuroscience laboratory under the tutelage of the director of that lab, or another scientist assigned by the director, such as a postdoctoral fellow. This model mirrors common research experiences in many undergraduate programs. Although there is general consensus that this approach is effective for student recruitment into the sciences, research on the topic is limited (NRC, 2003; Russell *et al*., 2007; Seymour *et al.*, 2004). Therefore, we are comparing its outcomes with those of our explicitly collaborative-learning model. For assignment within the AM, participants were matched by interest with faculty mentors and immersed into extant research groups as interns. Mentors were encouraged to involve participants in all aspects of their research. The only requirement was that each AM student's experience would culminate with preparation of a final research report and a poster for the symposium.

3.2 Participants

Although the study has been conducted with three full cohorts of approximately 40 participants each in 2009, 2010, and 2011, the individuals of focus for the present report participated in summer 2010. Thus we limit our analysis to the 2010 cohort for this report, and it included 23 female and 13 male participants. Their self-identified ethnicity was as follows: Asian descent/Asian American (3), Caucasian (11), African descent/African American (11), Hispanic/Latino/Latina (7), Other (2), with two participants electing not to provide this information. They were distributed across academic years: freshman (9), sophomore (11), junior (8), and senior (8). The cohort was divided according to stratified random assignment into two experimental groups, with 18 participants in the CLM group and 18 participants in the AM group.

3.3 Data Collection

Project data collection included pre-, mid-, and post-program online surveys containing instruments to measure scientific research self-efficacy, leadership/teamwork self-efficacy, science identity, science anxiety, neuroscience anxiety, commitment to science, and other affective and program evaluation instruments. Additional measures of program outcomes included science content mastery quizzes during orientation and written research products submitted at the end of the program. These quantitative measures were coupled with interviews and focus group discussions conducted at the beginning and end of the program. Each participant was randomly assigned to either interviews or focus groups for both time points. Long-term academic achievement and career progress will be tracked following each participant's completion of the program.

Self-efficacy beliefs were measured quantitatively using an instrument developed by Chemers and colleagues (Chemers *et al.*, 2001). Students were asked to rate their confidence in their ability to complete tasks such as generating a research question to answer, figuring out what data to collect, creating explanations for the study's results, and relating results and explanations to the work of others. Thus, this domain of self-efficacy could be termed "scientific research."

3.4 Case Study of Four Selected Participants

We are presenting interview data from four participants who demonstrated different trajectories of scientific research self-efficacy; for two participants, scientific research self-efficacy increased over the course of the program and for two participants, it remained stable, one just above the median level for the 2010 cohort and one at a high level. Means and standard deviations for the cohort's self-efficacy scores were determined at the beginning, middle, and end of the program. To select case study individuals with increasing self-efficacy, we began with participants exhibiting low pre-program self-efficacy, and identified those participants whose trajectory was near the cohort mean at mid-program and well above the mean at post-program. In selecting cases with consistent self-efficacy scores, we identified those whose mid-program values were relatively close to their pre- and post-program values. In this way we selected four participants, two each from the above categories (see Fig. 1 and Table 1). We had originally intended to include two students whose self-efficacy had decreased; however, we identified very few students in that category. It was not possible to include them because the few students whose self-efficacy trajectories decreased had been assigned to focus groups, thus eliminating them from the pool for this portraiture.

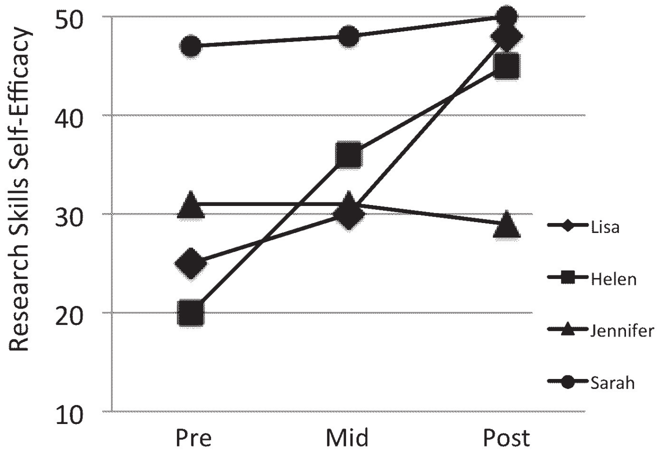

FIG 1: Scientific research self-efficacy as a function of time in the program

Four students' data are shown. Two students' research self-efficacy increased and two students' research self-efficacy remained relatively stable, with one remaining at a moderate level and the other at a high level.

The following is a brief overview of the four case study participants. The names used here are pseudonyms. Helen, an Asian American female, was a rising sophomore majoring in neuroscience at a southeastern two-year college. Her self-efficacy trajectory increased from the beginning to the middle and from the middle to the end of the program. Lisa, an African American female, was a pre-med biology major at a southeastern HBCU, entering her second year, but academically considering herself a junior. Her self-efficacy trajectory increased from the beginning to the middle and from the middle to the end of the program. Jennifer, an African American female, was a rising senior majoring in neuroscience and minoring in teaching, from a northeastern college. Her self-efficacy remained consistently near the median of the scale throughout the program. Sarah, a Caucasian female, was a graduated senior who majored in psychobiology at a southeastern college, and was entering a graduate program in science. Her self-efficacy remained consistently high throughout the program. These demographics are summarized in Table 1.

3.5 Interview Data Collection and Analysis

Each of the four students participated in two face-to-face interviews, one 2–3 days before the start of the program, another at the end of the program. To create an interview that was flexible enough to draw out individual views, while also ensuring consistency among interviews, we used an open-ended semistructured interview.

Interview questions aimed at eliciting students' beliefs about their ability to conduct scientific research; their future goals and career trajectories; and their ideas regarding the nature of scientific research, characteristics of the scientific community, and characteristics of effective mentors. The interview protocol was based on current self-efficacy and motivation research (Schunk, 1991; Zeldin and Pajares, 2000). Interviews were conducted by one of two researchers, audio recorded, and transcribed verbatim.

TABLE 1: Demographics of case study participants (CLM: collaborative-learning model; AM: apprenticeship model; SAT scores not available for Jennifer and Sarah)

Participant pseudonym	Program format	Academic year	Major	School	Self-efficacy trajectory	GPA	SAT scores			Prior scientific research experience
							Math	Verbal	Writing	
Helen	CLM	Rising sophomore	Neuroscience	Southeastern 2-yr college	Increase	3.92	740	700	790	56/100
Lisa	AM	Rising second-year junior	Pre-med biology	Southeastern HBCU	Increase	3.93	620	630	600	68/160
Jennifer	AM	Rising senior	Neuroscience (teaching minor)	Northeastern College	No change (moderate)	2.54				74/160
Sarah	AM	Entering graduate school	Psychobiology	Southeastern College	No change (high)	3.35				105/160

Coding of interview transcripts was conducted by three researchers using NVivo (2009). A sample of the interviews was cross-coded to establish inter-rater reliability. Subsequent analysis of the study data occurred in two phases. In the first stage we identified emerging first-level codes connected to students' descriptions of their scientific research self-efficacy, met periodically to discuss emerging findings, and created a set of codes that represented the first-level codes. We then grouped first-level codes into second-level codes and identified emerging themes in the data, comparing ways in which students with different trajectories of self-efficacy discussed their confidence and their career plans.

4. FINDINGS

The interviews were interpreted through the lens of Bandura's social cognitive theory (1986, 1997); in particular we focused on themes of self-efficacy and the four theorized sources of self-efficacy—mastery experiences, vicarious experiences, social persuasion, and physiological and affective states. In the following section we provide a detailed portrait of four individuals based on the themes which emerged from the analysis of the qualitative data, and we supplement those with quantitative data from the online surveys, as provided in Table 2.

4.1 Helen

Helen, an Asian American woman, was a rising sophomore majoring in neuroscience at a southeastern two-year college. She was the only case study participant from the CLM format, and was academically the youngest participant. She presented an outstanding academic profile with high scores on the Scholastic Achievement Test (SAT) and a high grade point average (GPA). Both her mother and father had graduate degrees. Yet she reported the lowest initial self-efficacy score, and her score on the pre-program research experience instrument was the lowest of the four, at 56 out of the maximum score of 160. Prior to her participation in our program, she had worked for two months in three different labs. Accordingly, despite stating that she learned different techniques through these experiences, she expressed low confidence. In her interview, she stated that she was "*not that confident yet*" in her ability to conduct scientific research. Her low self-efficacy in this area was clearly attributed to a lack of mastery experiences. When asked about her prior experience, she stated "*I haven't actually sat down in, like, an actual project."* Another indicator of Helen's low initial self-efficacy was that she expressed some intimidation in relation to the binder of material and the textbook provided to participants before the first week of instruction in the program, referring in her pre-interview to *"…the giant list of protocols and the textbook that we had to read…*".

Her prior lab experiences provided some benefit in this area, however. When asked *how* her prior visits to several different labs had affected her confidence, Helen replied that "*I feel like I understand more about what's going on and different techniques*." When asked what her confidence was related to, she replied "*understanding and being able to do [research]*."

According to her survey responses, Helen's self-efficacy increased between the middle and end of the program. Interestingly, during her post-interview, Helen simultaneously indicated that she found research more challenging than she had previously imagined and that she was herself more confident in her own abilities after the BRAIN summer program. When asked whether her ideas about research had changed, she replied,

TABLE 2: Scores from online surveys for case study participants, as compared with the averages for their cohort

Participant pseudonym	Scientific research self-efficiency			Leadership teamwork self-efficiency			Science identity			Science anxiety			Neuroscience anxiety			Commitment to science			Average post-program learning gains
	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post	
Helen	20	38	45	44	47	45	29	30	27	13	13	14	14	10	13	25	28	24	3.77
Lisa	25	30	48	39	47	47	22	27	31	14	12	10	15	11	8	28	35	35	4.16
Jennifer	31	31	29	43	38	38	24	22	18	31	26	24	21	19	19	24	25	22	2.70
Sarah	47	48	50	49	50	49	35	35	35	9	9	9	12	8	8	35	35	34	3.03
Max score	50			50			35			45			40			35			
2010 Mean	33.88	37.47	42.35	40.50	44.68	42.88	26.26	28.56	28.18	14.53	14.29	13.85	14.53	11.79	12.08	28.59	30.91	30.15	3.34
2010 Std. Err.	1.4	1.03	1.07	0.71	0.79	1.11	0.97	0.84	0.89	0.902	0.902	1.01	0.63	0.82	0.91	0.84	1.08	1.09	0.12
2010 Count	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	38

> *I really think scientific research is a lot harder to do than I had imagined. When I was talking to my dad and some of his co-workers, they just made it seem very easy like, 'Oh, well I knew to do this, and this, and this because this and this happened.' Then my group and I were designing our experiment and there were just so many variables that we could choose. We spent hours arguing over almost everything, especially because one of our group members was a bit more on the argumentative side, which wasn't bad because she gave us like points of view that, 'Hey, you need to look at this from this point of view.' So, it took a lot to finally decide on our final project. (Laughter) But I definitely think that research is very valuable and scientists have it hard.*

Helen's discussions with her father and his co-workers, that formed an impression for her that science was "*very easy,*" is a form of vicarious experiences. However, in Helen's case it proved to be a good example of the dynamic nature of self-efficacy and the relative strength of mastery experiences over vicarious experiences as sources of self-efficacy information. Her own challenging experiences in the BRAIN program overrode the previous impressions she had gained from her father and his friends about the degree of challenge to be found in scientific research. This had a corresponding effect on her self-efficacy, which fortunately was not long-lasting, as she subsequently experienced her own positive mastery experiences in the BRAIN program, leading to an increase in her self-efficacy.

When asked if the BRAIN program had had an effect on her confidence to do research, she responded, "*I think I'm a lot more confident now than I was before.*" She attributed her higher self-efficacy to *"[having been] through the process once. So, next time, I'll know what I'm doing and what to look for in a project and how to design one."* She later expressed again that "*If I want to do research, then I know how to plan something well, an experiment, and conduct it.*" Both her perception of the challenges of research and her increasing research self-efficacy are based on her successful mastery experiences in the program.

Helen's comments about her increasing self-efficacy match the responses on her scientific research self-efficacy survey. Her overall score increased the most among all participants in her cohort, and she reported especially robust gains on several survey items: generating a research question, figuring out what data/observations to collect and how to collect them, figuring out what data/observations mean, and creating explanations.

Helen's increase in research self-efficacy also seemed to be reflected in her newfound sense of herself as a fledgling member of the scientific community. During the pre-interview she indicated that she did not consider herself a part of the scientific community; when asked during the post-interview, her response was:

> *So, before I didn't include students in the scientific community, I don't think. Now, I definitely think that students are part of the scientific community because we're the ones who are being trained and brought up to be the next scientists.*

The increase in her research self-efficacy has given her the confidence to consider herself a member of scientific community. In contrast to Helen's comments about confidence, these comments about membership in the scientific community are not reflected clearly in her survey responses. Her score on the survey subscale measuring "science identity" decreased, as did her reported sense of belonging to the scientific community and in the field of science. As would be expected, however, she reported that her social network included more scientists and/or science students at the middle and end of the program than at the beginning.

4.2 Lisa

Lisa, an African American woman, was a pre-med, rising academic junior entering only her second year in college, majoring in biology at a southeastern HBCU. She participated in the AM format. She joined the program with a strong academic profile, including good SAT scores and the best GPA of the four case study participants. Her mother was a college/university graduate and her father had attended college but not graduated. She reported no prior experience working in a faculty member's laboratory, though, with a prior experience score of just 68/160. This may have contributed to her relatively low initial scientific research self-efficacy score, the second lowest in this case study. Her self-efficacy trajectory increased from the beginning to the middle and again from the middle to the end of the program. When asked in the pre-program interview about her confidence in her ability to conduct scientific research, Lisa stated:

> *I'm not too comfortable with it yet. I think that's why I really wanted to do the internship so I can broaden those skills. So, I think once I get the techniques down and the process of it, I'll be fine. But, you know, I'm just a little anxious about the whole beginning of it.*

Lisa's response illustrates the connection between mastery experiences (wanting to broaden her skills, get the techniques down) and self-efficacy (not too comfortable with it). Her response also alludes to one of the other common sources of self-efficacy information, physiological and affective states (Bandura, 1986) in her reference to being anxious about the beginning of the program. Her initial anxiety was also reflected in her surveys; she scored close to the mean for the cohort on both the science and neuroscience anxiety instruments at the beginning of the program, and then her anxiety scores fell by the end.

Based on Bandura's (1986) concept of the contribution of mastery experience to the development of self-efficacy, in the pre-program interview, the interviewer inquired about prior research experiences that may have affected her confidence. Lisa replied:

> *Nothing really, except for the basic science labs in college. Then I was in their IB [International Baccalaureate] program in high school. So, we had to come up with our own little experiment-type thing. So, just small-scale type experiments, but nothing broad or grand. ...*
>
> *Interviewer: How have those things influenced your confidence?*
>
> *It's okay. I mean, I've done pretty well in those things, but they were, like I said, small-scale. So, I guess I'm more anxious about the larger scale type research experiences.*

Here again, Lisa refers to her previous mastery experiences as being insufficient to prepare her, and in this case, she links anxiety more specifically to research. Lisa again expressed anxiety and a lack of confidence when asked about her career plans. "*I want to go into medicine and research. So, MD/PhD is what I'm looking for. I'm pretty nervous about that, whether I'd get in or not. I know it's really competitive*." Anxiety is not only a source of information for the formation of self-efficacy beliefs (Bandura, 1986), but a common result of being faced with science-related situations in which one has low confidence that one has the skills needed to succeed (Mallow, 2006).

Like Helen, Lisa's survey responses about her scientific research self-efficacy indicated increasing self-efficacy between the middle and the end of the program. According to Lisa, who participated in the AM, the BRAIN program "*definitely*" influenced her confidence in her ability to conduct scientific research effectively. She stated,

> *This is my first research experience besides, you know, the little labs that go along with the lectures in college.*
>
> *I definitely feel more confident in realizing what's going on, and how things happen, and what it actually takes to be a researcher.*
>
> *Like I said, our mentor, you know, she let us go for it, like trying to figure it out ourselves. So, just I guess growing my own analytical skills and how I see things and just trying to see it from a different perspective.*

Lisa was the only one of the four participants who spoke spontaneously of the importance of her self-efficacy or confidence. When discussing collaboration, she indicated that she did not engage in a lot of collaboration because "*I guess just developing my own confidence in research first was more important to me*." Lisa's survey responses indicated the greatest gains in her ability to generate a research question to answer, to develop theories, and report results in written or oral format.

No mention of anxiety occurred in Lisa's interview at the end of the program. Her self-efficacy may have increased during the program in spite of the anxiety she was feeling, or it is possible that the way in which she dealt with her anxiety contributed to her heightened self-efficacy about research. Moreover, her science and neuroscience anxiety scores did decline slightly during the program, suggesting that she may have learned how to cope with her anxiety, or that concomitant increases in self-efficacy relieved some of her anxiety. In any case, it is the manner in which anxiety affects behavior, or the way in which individuals interpret their anxiety that is most influential on self-efficacy; debilitating nervousness is likely to compromise self-efficacy, whereas accepting stressful experience as a challenge or motivator is likely to promote gains in self-efficacy (Bandura, 1986).

4.3 Jennifer

Jennifer, an African American woman, was a rising senior majoring in neuroscience and minoring in teaching, from a northeastern college. She was in the AM. Although her SAT scores were not provided, her academic profile may have been the least impressive among those in the case study, given her relatively low GPA. Her mother was a college/university graduate and her father attended but did not graduate. With regard to prior research experience, Jennifer had worked in a faculty member's research laboratory for multiple years, and logged some other preparatory experiences, leading to a mid-range "prior experience score" of 74/160. She reported an initial level of self-efficacy slightly higher than that of both Helen and Lisa, but still only slightly above the middle of the Likert-scale range. At the start of the program, Jennifer stated that she did not know whether she could comment on her ability to conduct scientific research effectively. However, she went on to say "*The little [research experience] that I have, I felt pretty confident. But I haven't had the most experience conducting my own experimental research*." She described her limited experience as consisting of working

> *…in the lab as a freshman just helping people with their honors projects. All seniors are allowed to do honors research projects. So, I helped some of them out. I've taken lab courses where as a class we designed an experiment, and run the experiment and do all the processes. But I've never had an individual experimental question that I've wanted to answer that I've run completely. So, that's probably my experience.*

At this point there was a match between Jennifer's limited previous mastery experiences and her moderate level of research self-efficacy. She expressed a feeling of success and confidence in the experience which she had to date, but because this was a minimal level of experience, it did not translate into strong research self-efficacy.

Jennifer's self-efficacy survey responses remained at this level throughout the program. While she started out reporting slightly higher research self-efficacy than Helen and Lisa, she ended the program with the lowest self-efficacy score of the four cases, but this is due to the rise in Helen and Lisa's self-efficacy scores and not a decrease in Jennifer's score. In terms of specific items on the self-efficacy instrument, Jennifer actually reported declines in several items, such as confidence with technical skills, data collection, and developing theories, although these were balanced by a few that increased, such as relating results to other literature.

Jennifer's case, however, provides an example in which interview data offer a more complete picture of the participant's research self-efficacy than quantitative data allow. Although her research self-efficacy remained level throughout the program, as measured by the survey, when asked during the post-interview if the BRAIN program had influenced her confidence, and if so, in what areas, she replied, "*I think it increased and decreased my confidence at the same time*." When asked to explain, Jennifer's answer referred to two aspects of research. One focus was the research model of working with rats and the other was communicating research results:

> *So, I have a lot of experience with rats in my previous lab. So, it just confirmed my confidence that, you know, I'm pretty comfortable with animal research in rats at least. You know, I can learn research projects pretty easily and do tasks pretty easily. But it also decreased my confidence in my ability, I guess, to write with the writing project at the end. I struggled pretty hard with that. So, just because I hadn't had that experience before, you know, writing the full research paper. So, writing is something if I decide to continue in this field, it's something I need to work on a lot. So, it was good to at least figure that out.*

Here, Jennifer indicates that one aspect of her research self-efficacy, working with rats and research projects in general, has increased, while another aspect, writing the research paper, has decreased. Her comments in these areas correspond with research findings that mastery experiences, both positive and negative, are often the strongest sources of information for self-efficacy beliefs. In Jennifer's case, her work with rats bolstered her previous positive experiences with this animal model and increased her confidence that she could continue to succeed in this area. However, her struggle with writing the research paper was a new experience; given no previous positive mastery experience in this domain, she was left with lower self-efficacy here. When asked to comment on her confidence with research techniques, Jennifer responded,

> *We learned some, like how to implant cannulae in the hippocampus. You know, I wouldn't call myself a master of that technique, but I definitely think that was one technique I learned over the summer that I'm glad I did.*

Again, we are reminded of Bandura's (1986) assertion that it is an individual's *interpretation* of an experience that is critical in the development of self-efficacy beliefs; Jennifer recalls learning how to implant cannulae but reports modest confidence in the technique, which is in line with her self-report of modest levels of self-efficacy on the survey. Unfortunately, alignment between these descriptions from her interview and individual items on the self-efficacy survey is not clear. For example, given her stated concerns about writing her research report, we would expect to see a decline in score on the item "report results in written or oral format," but instead see stable ratings at the mid-range of the Likert scale at all three data collection times. Perhaps Jennifer was more comfortable with presenting results in oral format, than in written format, and the combination of the two in the survey item interfered with the alignment to her statements, which were specific to writing. Mismatches like these could be explained by numerous factors, none of which is mutually exclusive: (1) we need multiple items related to a particular skill on a survey in order to draw valid conclusions from survey responses, (2) survey items that we align with participant interview comments do not align from the students' perspectives, (3) the validity of one or the other assessment approach is compromised.

This mix of positive and negative self-efficacy was also apparent when Jennifer was asked about her confidence in being able to work as an individual or a collaborative researcher:

> *I think as a collaborator, I think I work well in a team. You know? As an individual, sometimes I kind of slack off a little bit. I think it's nice to work in a group, because they push each other and they push work harder. I think as an individual, it's easier to, you know, procrastinate or lack something. So, I think me pushing my individual effort more is something I could work on. But I think as a group, I think I'm a good team player.*

She expresses confidence in her ability to work as a collaborative researcher but less confidence in her ability as an individual researcher. Again these comments fail to align with Jennifer's survey responses; we would expect to see an increase in leadership/teamwork self-efficacy accompanying this reported confidence in her ability to collaborate, but instead Jennifer's scores on this scale declined.

Jennifer was characterized as a participant whose self-efficacy trajectory remained level throughout the program. However, the interview allows a more complex portrait to be drawn of an individual whose confidence has increased in some areas and declined in others. This is brought out in the interview and prompted a more detailed analysis of individual survey items, and thus illustrates the benefits of a mixed-methods research model.

4.4 Sarah

Sarah, a Caucasian woman, was a graduated senior in psychobiology, headed toward graduate school, and academically the most senior program participant. She was in the AM. Her SAT scores were not provided and her GPA was in the middle of the four case study participants. Her mother was a college/university graduate and her father had gone on to graduate/professional school. She had extensive experience with research and related activities before the program began, with a total prior experience score of 105/160. The few low points in her background included no experience giving presentations at professional conferences, no peer-mentoring, and never having been paid a stipend for her laboratory work. It follows that Sarah reported the highest initial self-efficacy score, which remained consistently high throughout the program. In the interview Sarah stated that she was "*ninety-five percent confident*" in her ability to conduct scientific research effectively. She attributed this to having previously

> *…performed like three experiments, like one experiment totally by myself, then one experiment, like data collection with people. But I formed a question and I answered the question by myself. Then one was like an introductory experiment. I feel I've been more of like a leader in those aspects. If I come up with a complication, I've found ways to get around it. I feel that I'm a strong scientific paper writer.*

This description of prior experiences speaks strongly to the effect of mastery experiences as a foundation of strong self-efficacy beliefs. As with the other participants, Sarah mentioned mastery experiences most clearly among the four sources of self-efficacy. She also noted the importance of working with someone already in the field, in order to get that experience: "*Working under someone would be great [to] get to experience. Like that's what I'm here for, the experience.*"

Although Sarah did not speak directly of vicarious experiences strengthening her self-efficacy or confidence, in her pre-interview she did refer to working with other researchers, when asked whether she would maintain research relationships with anyone from the BRAIN program.

> *I mean, I'm interested in primates, so really anybody that is interested in primates as well. Like I'm not sure if I want to do like lab work or field work. But I think that, you know, being in contact with anyone really from the primate world would be really good for me.*

Again, in her post-interview, she mentioned the value of working with and observing others who are in the positions to which she aspires:

> *I thought the advantages were it was more in-depth and you kind of got to see like what it's like to be in a real-world lab, which I thought was really cool. You know, you get to see the actual process and the actual like scientists that are publishing and what their process is, and how they work.*

She clearly values the ability to observe models at every level in the field of research so early in her career, and mentions being able to observe their processes, ask them questions, and see what she refers to as a "*real-world lab*." These experiences observing others in the career field to which she aspires are examples of the vicarious experiences that Bandura (1986) theorized make significant contributions to increased self-efficacy.

Sarah's self-efficacy survey responses remained high between the middle and the end of the program. When questioned after the program, at first Sarah did not feel that the BRAIN program affected her already high confidence in conducting scientific research, stating that the seminars and orientation were "*basically reviews of what I had done already in college*." However, she did state that the research experience provided "*a more in-depth and scientifically important research, I think that made it better and made me understand a little more*." When asked about the program's impact on her confidence in performing different techniques, she replied with reference to a more narrow skill set:

> *Yeah. Well, I am confident in the technique that I did, which was like learning with monkeys. (Laughter) So, I mean…*
>
> *Interviewer: Was it one technique that you learned?*
>
> *Yeah. I mean, well I guess I learned several. So, yeah. Because I did like histology sometimes. I did another like eye movement technique. So, yeah. I mean, they're specific to monkeys, but the histology was interesting and I felt more comfortable with that.*

She also expressed an increased confidence in her ability as an independent researcher:

> *Like I'm becoming more confident and able to answer my own questions and they be significant, instead of in college or something you're answering questions that have been answered before or simpler. Whereas, like now I can do more in-depth that may have an impact on some school of thought or something like that –*

During a discussion with the interviewer about the nature of the scientific community, Sarah expressed her growing confidence in her ability to be an effective member of a lab group.

> *I'm more confident in that I'm capable of being involved in a big lab and contributing to their data collection and research and stuff.*

Thus, in her post-interview, Sarah expressed increased confidence in her abilities in specific laboratory techniques, to answer her own research questions, perhaps have an impact on the field of neuroscience, and her ability to contribute effectively to a research team.

Sarah was initially selected for this study because her quantitative results identified her as a participant whose self-efficacy had remained level during the course of the program. However, this may not actually be the case, as is indicated by her responses from the interview; it may instead be a case of a participant expressing an initially strong sense of self-efficacy on the quantitative survey by selecting the highest response possible on the Likert scale. This strong self-efficacy was the result of previous mastery experiences, as she was academically senior to other participants, and she had the highest number of research experiences and science courses prior to the program. In the interview, many of her comments indicated that her self-efficacy had increased through the activities of the program. Because she had initially responded near the top of the quantitative scale, her case may reveal that our instrument is not sensitive enough at the high end to capture gains made by students entering the program with high self-efficacy, thereby creating a ceiling effect. The more open-ended probes of the interview, as well as the opportunity to expand on her responses, allowed her to describe her increasing sense of self-efficacy, whereas the format of the survey limited her responses. As with the prior case of Jennifer, this confirms the beliefs of many researchers that the best results come from a mixed approach to self-efficacy research (e.g., Pajares, 1996, 1997; Schunk, 1991).

4.5 Summary

Regardless of the self-efficacy trajectory that led to their being selected for this case study, all four of the participants expressed an increase in their confidence in their ability to carry out some aspect of neuroscience research (e.g., asking experimental questions, designing experiments, collecting data using particular techniques). One of them also described a decrease in her confidence in other aspects of the research process (i.e., written scientific communication). When asked to describe how the BRAIN program had influenced their confidence, all four young women spoke most consistently of mastery experiences. In addition, two women spoke of vicarious experiences and one of physiological and affective states in the form of anxiety. None of them described social persuasion. The interviews of two students revealed different self-efficacy portraits than expected from their quantitative data, thereby underscoring the importance of mixed-methods research.

5. DISCUSSION

With the strong emphasis on mastery experiences reported by the participants in our case study, we are drawn to Bandura's (1986, 1997) theorizing about the importance of the individual's *reflection* on and *interpretation* of these experiences. It is this reflection and interpretation that ultimately influence the effect of mastery experience on self-efficacy. Interviews with the study participants revealed that students interpreted general, program-based experiences in unique, individual ways. For example, Sarah, who reported consistently high levels of self-efficacy on the survey, focused on a more narrow and advanced set of skills in her reflection when she discussed her increased confidence in the interview. Jennifer, with consistently lower reported self-efficacy, disclosed a more complex pattern of self-efficacy in the interview, with increases in some areas (lab techniques and collaboration) and decreases in other areas (reporting results and independent work). Consequently, the mastery experiences embedded in the program had differing influences on the self-efficacy of the participants.

Bandura (1997) identified situational factors that can affect an individual's interpretation of mastery experiences. Several components of the BRAIN program relate to these factors, and thus may have contributed to the significant increases in self-efficacy found in the quantitative data in the larger study, as well as the specific gains discussed by the participants in the present case study. The following factors are examples:

(a) *Persevering in the face of challenges, and overcoming setbacks.*—Within the scope of the BRAIN program, participants are supported by mentors and program administrators when they meet challenges or setbacks, assisted as they figure out what skill sets they need to further develop, and encouraged to map individual pathways to success.

(b) *Modeling of successful strategies.*—With both the CLM and AM approaches, participants have mentors and peers who model strategies successful for the research environment, including specific lab techniques, research design, and career paths.

(c) *Cognitive simulations of successful performances.*—Although the focus of the BRAIN program is integration of students into authentic research environments, instructional demonstrations involving experimental design, along with journal clubs in which next steps for a line of research are discussed. Both provide exercises in "thinking like a scientist."

(d) *Having mastery experiences organized in ways that are conducive to the acquisition of generative skills*.—Learning skills in such a way that they can be accessed when they are needed in future situations is another important factor. In the AM approach, participants are working in ongoing research programs. In the CLM approach, participants design and investigate their own research questions. In both of these models, participants are learning skills applied in active research environments, rather than as isolated skills, which increases acquisition, retention, and application of those skills.

(e) *Support in cognitively processing their performances*.—The accurate and timely reflection on, and interpretation of, an individual's mastery experiences is critical to the formation of an optimal level of self-efficacy (Bandura, 1986). Participants in the BRAIN program receive feedback on their performance from the mentors with whom they were matched at the beginning of the program (in the AM), from instructors, mentors, teammates, and labmates who contribute to formulation of research questions and experimental methods (in the CLM), from peers who help edit drafts of their final research posters, and from judges who complete a rubric assessing their poster presentations.

Although the four women in our case study cited only a subset of these factors as contributing to their research self-efficacy at the beginning or end of the BRAIN program, additional focused interviews might reveal their influence. Further research in this area would provide a mechanism to isolate the best practices in the program in order to help shape the BRAIN program and maximize student gains in research self-efficacy. This may allow the program to be implemented in a variety of institutions, including largely undergraduate-serving institutions, which may lack large groups of research faculty members.

While all of the participants indicated that they felt more confident at the end of the program, one of our case study participants realized that she was quite unsure of her ability in one area: written scientific communication. Given the importance of scientific communication in the community of science, the BRAIN program could benefit from exploring whether other participants also realize insecurities in certain aspects of research, followed by designing programmatic strategies to expand related skill sets. We may consider further individual item analysis of our quantitative data to confirm this finding and help refine program offerings.

The main focus of this case study approach to assessing student outcomes from our summer undergraduate research program was to listen to the voices of four young women in order to help us improve our own program for future participants. We can improve our program in several ways, including changes to the program components as well as changes to our target population to emphasize those individuals most likely to benefit from our program offerings. In light of the latter possibility, the two students in our case study who gained the most in self-efficacy (Helen and Lisa) were similar in several ways: both were academically young (entering their second year in college), academically strong (high GPAs), were attending a relatively small institution (small college or HBCU), and had some laboratory exposure but no in-depth research experience, significant existing inclusion in a scientific community, or high research self-efficacy to start. These characteristics differ from Jennifer, whose mid-range self-efficacy did not change in our program: Jennifer was not academically strong to start, entered with some research experience and corresponding mid-range initial self-efficacy, but later revealed true interest in a medical career. Sarah was different from all of the others: she was not academically strong in terms of GPA, but had significant initial research experience, a feeling of belonging to a scientific community, and initially very high scientific research self-efficacy and commitment to science. Sarah had very little room to grow on our measures of self-efficacy and related constructs, although her interview did reveal some areas of scientific maturation. Thus the target population for a program like BRAIN may include students who are academically young and academically strong, with some laboratory exposure, but low scientific research self-efficacy and belonging in the scientific community.

Another motivation for the current study was to help confirm for the scientific community that getting students involved in research is a worthwhile endeavor. In particular, given our comparison of two program formats, the similarity we recorded in the experience of our one case study participant in the CLM with the three participants in the AM suggests that both program formats provide mastery experiences that may serve as mechanisms to influence scientific research self-efficacy. This is especially important in light of the concern that the pool of available mentors is often too small to accommodate the number of students interested in participating in authentic research. This lack of opportunities may affect recruitment and retention in the scientific community, especially for students attending institutions with small numbers of research faculty mentors. This may be most likely to affect recruitment of women and minorities, given that women's colleges and minority-serving institutions tend to be smaller than other institutions and sometimes do not sustain major research programs. Coupled with our quantitative survey data indicating that both models were equally successful in raising self-efficacy, our study suggests that the CLM can be substituted for the AM when institutions or departments cannot support the AM. Scaling up the CLM suggests promising future work in non-research-intensive institutions, thereby significantly expanding student opportunities in research.

Specific gains in scientific research self-efficacy reported in the post-interview by our case study participants, coupled with the overall statistically significant gains made by the larger group of participants in the ongoing study on the BRAIN program, reinforce the claim that undergraduate research experience aids the trajectory toward successful research careers (Russell *et al.*, 2007). Given that it is well established that science and math self-efficacy predict progress toward and success in careers related to STEM fields (e.g., Lent *et al.*, 1986; Zeldin *et al.*, 2008), the present study suggests that our BRAIN program will facilitate recruitment and retention of the most talented individuals with diverse backgrounds in pathways toward scientific research careers.

REFERENCES

Bandura, A., *Social Foundations of Thought and Action: A Social Cognitive Theory*, Englewood Cliffs, NJ: Prentice Hall, 1986.

Bandura, A., *Self-Efficacy: The Exercise of Control*, New York: Freeman, 1997.

Britner, S.L., A qualitative stuy of the self-efficacy beliefs of successful African American men and women in mathematics, science, and technology careers (In preparation).

Center for Behavioral Neuroscience, *Strategic Plan by the Center for Behavioral Neuroscience*, Atlanta, GA, 1999.

Chemers, M.M., Hu, L., and Garcia, B.F., Academic self-efficacy and first-year college student performance and adjustment, *J. Educ. Psychol.,*vol. **93**, no. 1, pp. 55–64, 2001.

DeHaan, R.L., The impending revolution in undergraduate science education, *J. Sci. Educ. Tech.,* vol. **14**, no. 2, pp. 253–269, 2005.

Dirks, C. and Cunningham, M., Enhancing diversity in science: Is teaching science process skills the answer?, *Cell Biol. Educ*., vol. **5**, pp. 218–226, 2006.

Fencl, H. and Scheel, K., Engaging students: An examination of the effects of teaching strategies on self-efficacy and course climate in a nonmajors physics course, *J. Coll. Sci. Teach.*, vol. **35**, no. 1, pp. 20–26, 2005.

Goode, C.T., Britner, S.L., Gagne, P., Pecore, J.L., Demetrikopoulos, M.K., Williams, B.A., Carruth, L.L., DeHaan, R.L., and Frantz, K.J. (2012). Scientific research self-efficacy among undergraduates: Current contexts and approaches for measurement, In S.L. Britner (Ed.) Self-Efficacy in School and Community Settings (pp. 21–52). New York: Nova.

Halme, E.G., Khodor, J., Mitchell, R., and Walker, G.C., A small-scale concept-based laboratory component: The best of both worlds, *Cell Biol. Educ.*, vol. **5**, pp. 41–51, 2006.

Kardash, C.M., Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors, *J. Educ. Psychol.,* vol. **92**, no. 1, pp.191–201, 2000.

Lent, R.W., Brown, S.D., and Larkin, K.C., Self-efficacy in the prediction of academic performance and perceived career options, *J. Couns. Psychol.,* vol. 33, no. 3, pp. 265–269, 1986.

Lopatto, D., Undergraduate research experiences support science career decisions and active learning, *CBE: Life Sci. Educ.,* vol. **6**, pp. 297–306, 2007.

Mallow, J.V., *Science and Anxiety: Research and Action*, *Handbook of College Science Teaching*, pp. 3–14, Arlington, VA: NSTA, 2006.

NRC, National Research Council: Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics, Committee on Recognizing, Evaluating, Rewarding, and Developing Excellence in Teaching of Undergraduate Science, Mathematics, Engineering, and Technology, Center for Education, Division of Behavioral and Social Sciences and Education, National Academy Press, 2003.

Pajares, F., Self-efficacy beliefs in academic settings, *Rev. Educ. Res*., vol. **66**, pp. 543–578, 1996.

Pajares, F., Current directions in self-efficacy research, in M.L. Maehr and P.R. Pintrich, Eds., *Advances in Motivation and Achievement*, Greenwich, CT: JAI Press, vol. **10**, pp. 1–49, 1997.

Peterson, S.E. and Miller, J.A., Comparing the quality of students' experiences during cooperative learning and large-group instruction, *J. Educ. Res.,* vol. **97**, pp. 123–133, 2004.

Russell, S.H., Hancock, M.P., and McCullough, J., Benefits of undergraduate research experiences, *Sci.,* vol. **315***,* pp. 548–549, DOI: 10.1126/science.1140384, 2007.

Ryder, J., Leach, J., and Driver, R., Undergraduate science students' images of science, *J. Res. Sci. Teach.,* vol. **36**, no. 2, pp. 210–219, 1999.

Schunk, D.H., Self-efficacy and academic motivation, *Educ. Psychol*., vol. **26***,* pp. 207–231, 1991.

Seymour, E., The loss of women from science, mathematics, and engineering undergraduate majors: An explanatory account, *Sci. Educ*., vol. **79**, no. 4, pp. 437–473, 1995.

Seymour, E. and Hewitt, L., *Talking about Leaving: Why Undergraduates Leave the Sciences,* Boulder, CO: Westview Press, 1997.

Seymour, E., Hunter, A-B., Laursen, S.L., and Deantoni, T., Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study, *Sci. Educ.*, vol. **88**, no. 4, pp. 493–534, 2004.

Treisman, P.U., Studying students studying calculus: A look at the lives of minority mathematics students in college, *Coll. Math. J*., vol. **23**, no. 5, pp. 362–372, 1992.

Zeldin, A.L., Britner, S.L., and Pajares, F., A comparative study of the self-efficacy beliefs of successful men and women in mathematics, science, and technology careers, *J. Res. Sci. Teach*., vol. **45***,* pp. 1036–1058, 2008.

Zeldin, A.L. and Pajares, F., Against the odds: Self-efficacy beliefs of women in mathematical, scientific, and technological careers, *Am. Educ. Res. J*., vol. **37**, pp. 215–246, 2000.