AC 2008-592: UTILIZING A SOCIAL COGNITIVE THEORETICAL FRAMEWORK TO INVESTIGATE THE INFLUENCES OF A SUMMER UNDERGRADUATE RESEARCH EXPERIENCE ON PARTICIPANTS' ACADEMIC AND CAREER PLANS

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Utilizing a Social Cognitive Theoretical Framework to Investigate the Influences of a Summer Undergraduate Research Experience on Participants' Academic and Career Plans

Abstract

Undergraduate research experiences in engineering have recently received significant interest as mechanisms for attracting undergraduates to graduate-level work. In particular, the National Science Foundation's Research Experiences for Undergraduates (REU) initiative aims to recruit students to careers in research. Our work employs a social cognitive theoretical framework to investigate how participation in a summer undergraduate research program influences participants' academic and career plans (specifically plans to pursue a Ph.D.) and their self-efficacy for future scientific research. A mixed-methods approach, incorporating survey instruments, interviews, and weekly self-reflective journal entries, was utilized to study undergraduate researchers (*N*=10) participating in a REU program at a large research university. A key finding from the qualitative data was the role that graduate mentors played as "coping models" in developing undergraduate participants' self efficacy, and consequently, their academic and career plans involving doctoral-level work. This study has implications for better understanding the advantages of summer undergraduate research experiences such in recruiting and retaining qualified students for graduate studies and research careers. In particular, these data make the case for fostering formal and informal interactions between graduate students and undergraduate researchers and for including specific opportunities for participants to learn vicariously through coping models that they perceive to be similar to themselves.

Introduction

As our nation seeks to expand and diversify its scientific workforce, undergraduate research experiences have garnered more attention and funding, with the goal of attracting and retaining talented engineering undergraduates into graduate-level work and, subsequently, research careers. The National Science Foundation's Research Experiences for Undergraduates (REU) program is one of the largest initiatives supporting active research participation by undergraduate students in all of the areas of research funded by National Science Foundation (NSF). The REU program solicitation[1] describes the initiative: "The REU program is a major contributor to the NSF goal of developing a diverse, internationally competitive, and globally-engaged science and engineering workforce. It draws on the integration of research and education to attract a diversified pool of talented students into careers in science and engineering, including teaching and education research related to science and engineering, and to help ensure that these students receive the best education possible."

With more than 600 sites around the world, the REU program presently funds 1,000 active awards, with approximately $327 million awarded to date. From these active REU awards, 385 (38%) are related to engineering (determined by having 'engineering' as a keyword in the title and abstract) and account for about $170 million, about half of the total amount of awards to date. In spite of such widespread support and belief in the value of undergraduate research to improve education, limited well-grounded research and evaluation studies exist to assess research-based learning.

The University of Houston (UH) Research Experiences for Undergraduates (REU) Site "Innovations in Nanotechnology" hosted ten students from six universities for ten weeks during the summer of 2007. Nine faculty experts from three departments (Chemical and Biomolecular Engineering, Mechanical Engineering and Electrical and Computer Engineering) in the College of Engineering served as research mentors. Graduate students, and in some cases, post-doctoral fellows also served as mentors for participants. Given the National Science Foundation's goals for the REU initiative, the UH REU site was designed to provide participants with a positive laboratory experience as well as significant professional development and social components. Weekly professional development sessions included a panel discussion with current engineering graduate students and professors on the topics of applying to graduate school and academic and industry career opportunities, as well as several weeks of written and oral technical communications instruction and practice. Participants were housed in on-campus furnished apartments, and social activities designed to foster camaraderie among participants were coordinated by a University of Houston student. The social activities coordinator organized and attended events showcasing the Houston area at least weekly.

One of the most prominent studies on undergraduate research has been the work of Elaine Seymour and her research group[2, 3]. Their five-year study on undergraduate research in STEM disciplines focused on four liberal arts colleges with a long history of undergraduate research programs. The work presented a comparative analysis of faculty and administrator interviews (N=80) with student interviews (N=76) and provided findings of the role of undergraduate research experiences in encouraging intellectual, personal and professional development of undergraduate student researchers. More specifically, the following category list of gains were identified: (a) thinking and working like a scientist, (b) "becoming a scientist," (c) personal/professional gains, (d) clarification/confirmation of career plans, (e) enhanced career/graduate school preparation, and (f) other gains and skills. The findings showed a high level of agreement between students (92%) and faculty (90%) that the undergraduate research experience was highly beneficial[2]. Although the work of Seymour and colleagues revealed findings pertaining to attitudes toward graduate school and research, as well as confidence levels and other gains in skills, the number of engineering student participants was limited to a small number.

Most recently, one of the more extensive studies on assessing the benefits of undergraduate research experiences was conducted by SRI International, under contract to the NSF[4, 5]. The study involved a nationwide, large-scale evaluation of undergraduate research, encompassing science, technology, engineering and math (STEM) and social, behavioral, or economic sciences. With 3,400 individuals surveyed over a period of three years the study focused on research participation and research experience effects. Some of their major findings from the STEM individuals are: (1) undergraduate research experiences were important in shaping career decisions and interests, (2) undergraduate research, especially sponsored research, seemed to encourage individuals to pursue a doctorate, (3) no statistically significant differences in perceived gains between men and women were evident, but African Americans and especially, Hispanics/Latinos were more likely than Asians or non-Hispanic Whites to have shown gains in understanding, confidence, and awareness. Although this was a large-scale study with 582 engineering graduates surveyed (this number included participants and non-participants of undergraduate research), in depth inquiry about the benefits of undergraduate research, skill gains, learning outcomes, and research on how the social cognitive aspects of the experience shaped the participants' career plans were not assessed. Thus, it is essential that we better understand and research the bodies-of-knowledge, learning outcomes, and social cognitive influences comprising of the countless ways in which students benefit and learn from being involved in undergraduate research.

Theoretical Framework

Based on the NSF goal of attracting students to research careers in science and engineering, one useful framework for investigating the influences of a REU experience on participants' academic and career plans is social cognitive theory. In this paper, we employ this theoretical framework to investigate how participation in a summer undergraduate research program influences participants' academic and career plans (specifically plans to pursue a Ph.D.) and their self-efficacy for future scientific research. This theoretical framework is rooted in Bandura's theory of self-efficacy[6], which can be defined as "a person's beliefs about his or her ability to perform a given task or behavior"[7]. Bandura[6] describes four sources of self-efficacy: past performance accomplishments, vicarious learning, verbal persuasion and emotional arousal.

Betz and Hackett[7] initially applied self-efficacy to career choice, hypothesizing that an individual's accomplishments and persistence in their chosen college major and career is related to self-efficacy. Lent, Brown and Larkin[8] further investigated the role of self-efficacy in performance and persistence by studying science and engineering undergraduates. Later, Lent Brown and Hackett[9] integrated self-efficacy expectations into their model of Social Cognitive Career Theory (SCCT), which describes a multi-faceted relationship between an individual's social environment and his/her career choices. According to SCCT, one's degree of persistence and performance depends on: self-efficacy, outcome expectations (belief about what will occur if one engages in certain activities), distal and proximal contextual (environmental) influences, and person variables such as gender and ethnicity. These factors directly influence or moderate an individual's career choice process—that is, the process of *interests* becoming *goals* and goals becoming *actions*[9].

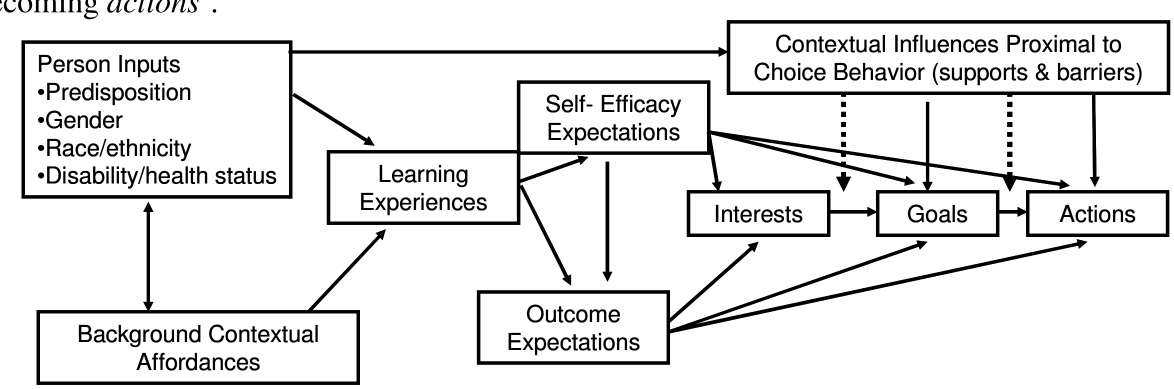

Figure 1. Social Cognitive Career Theory. Reprinted from Journal of Vocational Behavior, Vol. 45, No. 1, R.W. Lent, S.D. Brown, and G. Hackett, *Toward a Unifying Social Cognitive Theory of Career and Academic Interest and Choice*, Pages 79-122, Copyright 1994, with permission from Elsevier.

The current study utilizes SCCT with a particular emphasis on the potential for a summer research (i.e. learning) experience to contribute to the development of undergraduate students' self-efficacy for scientific research and graduate level work. In investigating the impact of a summer research experience from this perspective, we examine Bandura's sources of self-efficacy as they relate to such an experience:

1. Past performance accomplishments hold the most powerful influence on self-efficacy. Students need to experience accomplishments (mastery experiences) to develop self-efficacy for a particular task (research). A task that is too difficult or has a strong likelihood of failure will not increase self-efficacy, although successively more difficult tasks with continual feedback may improve self-efficacy[10]. Once self-efficacy is established, an occasional failure will generally not detrimentally affect self-efficacy, and in fact, overcoming such a failure may enhance it.

2. Vicarious learning (observational learning, modeling and imitation) is the second most powerful influence on self-efficacy. Students need to see role models achieve success in order to feel like they can do it, too. This is particularly important if the student has little prior experience or direct knowledge of the task, and is most influential when there is a perceived similarity (e.g. sex, race, age, socio-economic status) between the role model and the observer[10]. This suggests that it may be easier for undergraduate researchers to learn vicariously from graduate students modeling successful behavior than from professors if they perceive themselves to be more similar to the graduate student. Additionally, coping models—that is, someone who struggles at times but eventually achieves success—are generally more powerful than mastery models (watching someone "sail through" and easily accomplish a task)[10].

3. Verbal persuasion is believed to be a lesser influence, but potentially still important in developing self-efficacy. The influence of encouragement or discouragement depends on the perceived expertness and trustworthiness of the source. If the student believes the source of encouragement to be credible, it may enhance their self-efficacy.

4. Emotional arousal is another lesser influence on self-efficacy. Generally, high levels of stress or anxiety negatively impacts self-efficacy.

Research Questions

In this paper, we use a social cognitive approach to investigate the following two research questions:

1. How does participation in a summer research program influence participants' academic and career plans?
2. How does a summer research experience influence participants' self-efficacy for scientific research?

Participants and Procedure

Our sample consisted of 10 undergraduate researchers participating in the University of Houston's Research Experiences for Undergraduates program during the summer of 2007. Participants were recruited and selected from around the country. More specifically, participants came from six universities and their majors included engineering (biomedical, chemical, electrical and mechanical), chemistry, physics, and mathematics. The sample included one African American, two Asian Americans, six Caucasians, and one Mexican American student. The participants included five females and five males.

Approval was obtained from the University of Houston and Virginia Tech Committees for the Protection of Human Subjects. A mixed-methods approach incorporating survey instruments, interviews, and weekly self-reflective journal entries was utilized. Triangulation of data from the mixed-methods approach revealed emergent themes and insights that otherwise would have gone un-captured using quantitative data alone. A more detailed description of the potential benefits of such an approach can be found elsewhere[11].

Participants completed online pre- and post-program survey instruments, which were conducted as part of a larger National Academy of Engineering Center for the Advancement of Scholarship on Engineering Education (CASEE) Postdoctoral Fellowship project conducted at Virginia Tech. The University of Houston site was one of 22 NSF-funded summer REU sites to participate in the CASEE research project. The survey instrument, National Engineering Students' Learning Outcomes Survey (NESLOS) included over fifty learning outcomes, derived from the ABET criteria "3a-k." Results pertinent to the two research questions explored in this paper are presented here.

Individual semi-structured interviews[11] provided an open-ended format for exploring undergraduate researchers' perceptions in their own words. Participants discussed their academic and career plans and the impact of the summer research experience on their career decisions. Additionally, the undergraduate researchers completed weekly journal assignments documenting their progress in the summer program. With the participants' permission, interviews were recorded. Following transcription, interview transcripts and journal entries were read by both authors and a research assistant, and a list of emergent themes was made. In the initial list, 70 themes were identified. The transcripts were then coded in NViVo 7, a software package for qualitative data analysis, at the paragraph level using the list of themes. During the initial round of coding, six additional themes were identified and were added to the list, for a total of 76 themes. The entire set of interviews was then coded by one author and a research assistant, and another round of inter-rater comparison was conducted. Coding comparison reports were run, and all differences in coding were discussed and negotiated to consensus. Thus, the resulting inter-rater reliability among coders was 100%. Analysis of journal entries written by participants is ongoing and will be reported in the future.

Qualitative Results

Of the 76 emergent themes from the interview data, 22 related to academic and career plans and/or self-efficacy. Eight of the most prevalent themes (listed below) related to academic and career plans are discussed here in terms of contributions to the components of self-efficacy described by Bandura[10, 12].

- The REU program opened participants' eyes to Ph.D. work
- Participants changed their mind about academic or career plans as result of the research experience
- The REU program provided validation that participants' intended career path is the right one
- The REU program served as a "taste" of graduate school
- Participants gained independence from mentors
- Participants developed confidence gains during the program
- Graduate students and faculty served as role models
- Advice from graduate student mentors influenced participants' academic or career plans
- Participants received encouragement by faculty mentors to pursue Ph.D.

As a result of these efficacious experiences during the summer program, the overall effect of the program, according to participants, was one of increased or newly developed dedication to pursuing graduate level–and specifically, Ph.D.–work. The participants reported a number of examples of how the REU program *opened their eyes to Ph.D. work* (n=7, 11 references to this theme appeared in the interviews) and/or *changed their mind about academic or career plans as result of the research experience* (n=7, 12 references).

When discussing how the program made them aware of opportunities and advantages associated with obtaining Ph.D. and their increased self-efficacy to do so, participants made comments such as:

> "I've always wanted to go to grad school to get a Masters, but I wasn't sure how far I'd go. I think after this program, I'm interested in a Ph.D. now because I can see what it can open up for me."
>
> "I *want* to go to grad school now. I wasn't really excited before. So, you know, it's definitely made me want to do grad school. I've always wanted to probably be an engineering professor. I thought that'd be cool because I like teaching. I was a tutor in high school and stuff like that. But I knew I would have to get a Ph.D., and that was kind of the 'I don't know if I want to do this' part of it. And now that I've done this, the Ph.D. work doesn't seem so bad."
>
> "[the program] Opened my mind to different possibilities, and confirmed my interest in research. "

One student talked about her change in goals before and after the program by saying, "it [the survey] asked me if I was going to go to graduate school and I said 'no,' now I've changed my mind."

Specifically, students repeatedly talked about the panel discussion with graduate students and faculty as an informative experience in addition to their daily access to mentors:

"Well, there was one of our events that we do every Wednesday [in the REU program]… one of them was having a panel of people who were going for or had Ph.D.'s and they talked to us about benefits of a Ph.D. It definitely threw a kink into my plans; made me consider graduate school a little bit more. So, yeah, it gave me pause and [caused me to] think a little harder about everything."

1. Past Performance Accomplishments

The REU experience served as a positive performance accomplishment(s) for participants, and subsequently influenced their thinking about graduate school and/or research careers. This contribution to participants' self-efficacy emerged as one of four themes: validation that intended career path is the right one (n=4, 7 references), a "taste" of graduate school (n=8, 21 references), gained independence from mentors (n=6, 13 references), and confidence gains (n=10, 39 references).

For four students, the REU program served as *validation that their intended career path is the right one*. One student said,

"Well, I have been considering it [a career in research] before coming to this program and then I wanted to do research program and make sure I liked research before I devote my whole life to it …It helped finalize my decision to keep researching."

Another commented,

"The plans were starting to form, but it's really helping me solidify the confidence and it started to point me into which directions I should start looking at."

Eight of the ten participants (21 references) talked about the REU program as *giving them a "taste" of graduate school*. Their successes gave them a clearer picture of the environment and expectations of graduate school; observing the graduate students work also fulfilled the role of **Vicarious Learning** (see next section). In describing how the program served this purpose from technical, social, and educational standpoints, students made the following comments:

"[The REU program helped in] Getting to know basically how graduate school works and research in the lab, I think that had the most benefits to it."

"I think it definitely gave me a really good idea at what its like to be a graduate student and I think that is exactly what I wanted to get out of this REU program. Yeah, a much more realistic idea of what needs to be done when you are in graduate school and realistically how long things take and how much time you allocate."

"When I first came here, I thought everything was going to fall in line and I could do things at specific times and I would get so much done in a week. No, no, no, no, no. That's not how it works at all. Everything gets little hitches and then slows down and you can get challenged by learning how to fix things that break."

"I kind of know [now] what I'm getting into [in going to graduate school]."

Six of the ten participants (13 references) discussed *gaining independence from their mentors* as the summer progressed. One student said,

> "We had a few sets of experiments that we would repeat until we got satisfactory results... For the first few weeks he [graduate student mentor] would show me how to set up the experiments and play around with the [equipment] and after that I would set up the experiment, run … whatever we were doing and he'd just stop by and look to see what I got."

The fact that they were able to eventually run equipment and/or setup experiments without the help of their graduate student mentors was a source of pride for several students. One student said,

> "…but after the fourth or fifth time [helping the graduate mentor to use a piece of complex equipment], the grad students were like, 'alright, so you do it. I'll watch.' And now, now they refuse to do it because they don't want to waste their time and they know I can. That was a real neat part of it."

Another commented,

> "I interacted with my grad student and other people in my lab every day. My grad student would help me a lot more during the first couple of weeks and after that I became fairly self sufficient and just when I had questions or problems I would go to him… I could get here early, start my work, you know, and so when he came in to check what I was doing I could give him updates. I liked it like that."

All ten participants described *confidence gains during the course of the program,* either in specific technical areas (n=10, 25 references) or general confidence gains (n=9, 14 references). Confidence gains in specific technical areas included developing working knowledge of specific pieces of equipment, technical writing and communication, and a better understanding of the field. General confidence gains included developing confidence for conducting research as well as succeeding in graduate school. When asked if the REU program helped them gain confidence in themselves, participants' responses included the following:

> "Yes, I didn't think I could learn a computer program. I was forced to learn it and learn how to do it fast."

> "Yeah it did, I was really pleased that I got to learn a lot of different techniques."

> "Yeah, very much. Just getting out of 'I'm an undergrad' and 'I'm not worthy' type of thing and saying, 'OK, I can do this on my own now.' I know I can understand this, it's just being able to have somebody tell me the first time. I have enough confidence now to be like 'Please help me. Just explain it to me and I can do it on my own.'"

> "Oh definitely, definitely. No question. Before I came here... I didn't know how it [nanotechnology] worked, I didn't know why it worked. And now I'm here, I could tell you how to make nanostructures. I could tell you how the process actually works. I could

tell you about some of the research in the field, like what people are doing, what applications are, and that's really cool. And the other thing is this confidence building that I could do this job and if I want to go to grad school, which I do, that I would make it as a grad student."

2. Vicarious Learning

Nine of the ten REU participants (23 references) talked about *graduate students and faculty mentors serving as role models* for success. Two participants specifically mentioned that working with graduate students helped them to envision themselves as graduate students one day. Representative quotes include:

> "Working here among the grad students…seeing how they live, seeing their working schedules, seeing the difference, that was a really interesting point… That helped a lot. The panel [discussion with graduate students and professors about graduate school] helped so much because I could ask just about the experience and the stuff you don't really talk about as much in lab. Dr. X was able to really give us some insight..."

> "Yes. I especially liked the panel of graduate students that talked to us about their experiences….Finding out a little more about how the first year of graduate school usually goes and how people go about finding a program."

> "I've been asking them [graduate students] questions like 'Why are you continuing?'... I've been asking 'would you rather work for a couple of years before entering grad school?' but they say it's really hard to get back once you've stopped."

Eight students (17 references) discussed how *advice from graduate student mentors influenced academic or career plans.* Participants sought both general and specific advice from the graduate students with whom they had contact, some citing general encouragement (also **Verbal Persuasion**, see next section) from graduate students as a confidence builder for following through with their plans. For example, one student said:

> "They're letting us talk to the right people who are very encouraging to go to a graduate program and talking to people who are in graduate programs to let us know that it's not as scary as we thought."

Alternately, participants used graduate students as sources of information or advice about specific courses of action, such as working then going back to school for a Ph.D.:

> "Well, my graduate student mentor, he had worked for a couple of years and then was coming back to grad school and you know I talked to him about a lot in the beginning like what he thought, was that a good decision, and based on what he said and what I thought before I wouldn't do that— it [graduate school] is like a now or never kind of thing."

3. Verbal Persuasion (Encouragement and Support)

In addition to the aforementioned encouragement by graduate students, some students elaborated on the verbal encouragement given to them by their graduate student mentors:

> "Most of my fears are worrying about getting out and getting a job. The graduate students I've talked to make it seem easy because they're doing it and saying 'don't worry.' They're telling me that I'm qualified. It really helps to, kind of, build up the confidence about where to apply at least and whether not to consider the Ph.D."

In addition, four of the ten participants (8 references) received *encouragement by their faculty mentors to pursue a Ph.D.*

> "My advisor and the post doc I work with were really good and showed me the ropes and talking [*sic*] about graduate school and that sort of thing."

4. Emotional Arousal

While 9 of the 10 participants indicated that their projects were challenging, none reported negative feeling of stress or anxiety about their summer work.

Quantitative Results

NESLOS asked participants to rate a number of learning outcomes. Several highly rated learning outcomes are shown in Table 1.

Table 1. List of selected highly ranked learning outcomes at the end of the experience. Ranking is based on the percentage of students that rated the item with a "4" (agree) and a "5" (strongly agree).

Highly Ranked Learning Outcomes	Percentage
Communicate effectively with others	100%
Convey technical ideas in formal writing and other scientific/engineering documentation	100%
Conduct (or simulate) an experiment	90%
Convey ideas verbally and in formal presentations	90%
Gain confidence in myself	80%
Analyze and interpret data	80%
Apply experimental engineering/scientific tools (e.g., machining, oscilloscopes, instrumentation, laboratory equipment) in engineering/scientific practice	80%
Increase perseverance	80%
Recognize my strengths and weaknesses	80%

According to results from NESLOS, (1) eight participants stated that they spent 1 to 5 hours per week with their faculty mentor, one stated they spend 6 to 10 hours per week, and one spent 21-25 hours per week with their faculty mentor, as well as (2) four participants stated that they spent 1 to 5 hours per week with graduate student mentors, two stated they spend 6 to 10 hours per week, and three spent 21-25 hours per week with graduate student mentors. These statistics illustrate the participants' strong interactions with their summer faculty and graduate mentors.

As a result of the summer research experience, quantitative analyses of NESLOS revealed statistically significant differences ($p < .001$) in participants' knowledge gains pertinent to validating their career plans after graduation as well as their intentions to pursue doctorate degrees. Table 2 shows that 45% more students recognized what they wanted to do after graduation when comparing pre and post NESLOS results. Also, it appears that most students prior to participating in the summer REU program had plans to pursue at least a Master's degree, but only 45% of them had plans to pursue a PhD. After the experiences, 80% of the students "agreed" or "strongly agreed" that they planned to pursuing a PhD.

Table 2. List of four items from NESLOS pertinent to career-related outcomes. Values shown correspond to the percentage of participants who "agreed" and "strongly agreed" with the statement. [* $p < 0.001$]

Career-related NESLOS Items	PRE (n=9)	POST (n=10)	% Difference
Know what I WANT to do after graduation (get a job, go to graduate school, etc.)	55%	100%	45% *
Know what I NEED to do to attain the goals I have for after graduation	67%	100%	33% *
I am considering to pursue a Master's degree	100%	90%	-10%
I am considering to pursue a Ph.D. (doctorate) degree	45%	80%	35% *

Discussion

The top two ranked outcomes from the NESLOS survey pertained to students learning that research involves being able to communicate effectively and convey technical ideas in scientific documents. Conducting experiments and gaining analytical skills were some of the other outcomes that students highly rated. These are transferable skills that students can now employ in other settings. Data from the quantitative and qualitative portions of the study were triangulated as a means to determine the reliability of interview data. Several of the highly rated learning outcomes from the survey data corresponded to topics discussed in interview responses. For example, the learning outcomes, "Convey ideas verbally and in formal presentations" and "Convey technical ideas in formal writing and other scientific/engineering documentation" coincided with participants' reports that developing and giving presentations on their work and writing the final report contributed to their increased confidence in their abilities to conduct research and succeed in graduate school. Additionally, according to the survey, participants valued knowledge of career options and decisions—i.e. knowing what they need and want to do after graduation—as important learning outcomes of participating in the program. These survey items, along with plans to pursue a Ph.D., were ones in which participants showed significant changes in the pre- and post-survey. These quantitative results support qualitative results related to participants' extensive discussions about how the program served as a taste of graduate school, opened their eyes to obtaining a Ph.D., and gave them access to graduate students and professors who served as role models and sources of information about graduate school.

Combined with their performance accomplishments in the laboratory, this new knowledge about graduate school and potential career options as well as the vicarious learning that took place over the summer had the effect of increasing participants' self-efficacy for research and graduate studies. As a result, four students changed or solidified their career plans to include obtaining a Ph.D..

In the NESLOS survey, 80% of the students agreed or strongly agreed that the REU experience allowed them to gain confidence. One key finding of this work is the role that graduate student mentors played as *coping models* in developing undergraduate participants' self efficacy, and consequently, their academic and career plans involving doctoral-level work. Observing graduate students at work, talking to them about overcoming their challenges, and/or seeking their advice about career choices was discussed by every participant in the study. Consistent with Bandura's theory[10, 12], the tone of these discussions was often one of "if they can do it, I can do it, too." The participants' extensive discussions of the mentoring relationships they developed over the summer are also reflected in the amount of time spent with faculty and graduate mentors.

Social cognitive career theory highlights the importance of an individual's social environment in his/her career choices (Figure 1). In particular, this work examines a summer research experience as a "learning experience" described by Lent and colleagues[9], which influences both self-efficacy expectations and outcome expectations. Both of these in turn impact the process of an individual's interests becoming goals and goals becoming actions. Our data suggest that social interaction with graduate students and faculty both in and out of the laboratory were key in initiating participant's career development decisions (i.e. interests becoming goals and/or goals becoming actions) and outcome expectations (what participants expect to happen if they pursue a Ph.D.) . Subsequent follow up with participants in the future will reveal specific ways in which the program impacted career decisions. Follow up after the first semester following the program is ongoing. Of the nine responses received by the writing of this paper, all participants had kept in touch with their REU faculty/graduate student mentors or the program director by seeking advice and letters of recommendation for graduate school, two reported that the program impacted their course selection at their home institution, and eight of the nine plan to apply to graduate school.

In agreement with the studies of Seymour et al.[3], Hunter et al.[2], and Russell et al.[4, 5], findings from our effort have also illustrated similar benefits (e.g. career preparation and validation of career goals, recruitment to graduate school, professional skill gains) to those previously reported. Additionally, though, our mixed methods approach has allowed for a more direct focus on engineering students, measures of more specific skill gains as a result of participating in an REU, assessment of pre and post outcomes, triangulation of qualitative and quantitative metrics, and grounding of outcomes to social cognitive theory.

Our work has implications for better understanding the advantages of summer undergraduate research experiences such as an NSF REU program in recruiting and retaining qualified students for graduate studies and research careers. Specifically, it extends capacity for developing effective undergraduate research experiences by studying in-depth the means through which such experiences aid participants in developing and/or clarifying academic and career plans. Our data make the case for fostering formal and informal interactions between graduate students and undergraduate researchers and for including specific opportunities for participants to learn vicariously through coping models, especially ones which they perceive to be similar to themselves.

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Bibliography

1. *Research Experiences for Undergraduates Program Solicitation*. 2008 [cited February 22, 2008]; Available from: http://www.nsf.gov/pubs/2007/nsf07569/nsf07569.htm.
2. Hunter, A.-B., S. L. Laursen and E. Seymour, *Becoming a Scientist: The Role of Undergraduate Research in Students' Cognitive, Personal and Professional Development,*. Science Education, 2007. **9**(1): p. 36-74.
3. Seymour, E., A.-B. Hunter, S.L. Laurensen and T. Deantoni, *Establishing the Benefits of Research Experiences for Undergraduates in the Sciences: First Findings from a Three-Year Study.* Science Education, 2004. **88**(4): p. 493-534.
4. Russell, S.H. *Evaluation of NSF support for Undergraduate Research Opportunities: Survey of STEM graduates (Draft Final Report to the National Science Foundation).* 2005 [cited 2007 March 17, 2007]; Available from: http://www.sri.com/policy/csted/reports/.
5. Russell, S.H., M.P. Hancock, and J. McCullough, *The Pipeline: Benefits of Undergraduate Research Experiences.* Science Education, 2007. **316**: p. 548-549.
6. Bandura, A., *Self-efficacy: Toward a Unifying Theory of Behavioral Change.* Psychological Review, 1977. **84**(2): p. 191-215.
7. Hackett, G., D. Esposito, and M.S. O'Halloran, *The Relationship of Role Model Influences to the Career Salience and Educational and Career Plans of College Women.* Journal of Vocational Behavior, 1989. **35**(2): p. 164-180.
8. Lent, R.W., S.D. Brown, and K.C. Larkin, *Relation of Self-Efficacy Expectations to Academic Achievement and Persistence.* Journal of Counseling Psychology, 1984. **31**(3): p. 356-362.
9. Lent, R.W., S.D. Brown, and G. Hackett, *Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance.* Journal of Vocational Behavior, 1994. **45**(1): p. 79-122.
10. Bandura, A., *Social foundations of thought and action: A social cognitive theory*. 1986, Englewood Cliffs, N.J.: Prentice-Hall
11. Leydens, J.A., B.M. Moskal, and M.J. Pavelich, *Qualitative Methods Used in the Assessment of Engineering Education.* Journal of Engineering Education, 2004. **93**(1): p. 65-72.
12. Bandura, A., *The Explanatory and Predictive Scope of Self-Efficacy Theory.* Journal of Social and Clinical Pyschology, 1986. **4**(3): p. 359-373.