Tracking Research Self-Efficacy of Participants in an NSF Research Experience for Undergraduates Site

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Introduction and Background

Participation in research during undergraduate engineering and science programs has been shown to increase the retention of students into both technical careers and graduate studies.[1] Significant funding to support undergraduate student research in engineering and science is provided by the National Science Foundation (NSF) through its Research Experience for Undergraduates (REU) program. REU sites generally host between eight and ten students during the summer months to conduct research projects within a thematic engineering or science research area. The faculty administrators for these sites are often responsible for recruiting participants, providing a high-quality research experience, and facilitating workshops to help participants develop professional and research skills. When administering a REU program site, it may also be suggested, or even required, that a plan be developed to evaluate the effectiveness of the site's programming. Past and present REU administrators have used variety of routes for developing their evaluation plans, including: using published engineering education articles to develop an evaluation plan or integrating a social-science researcher who can advise on evaluation. The role of the social-science researcher can range between that of an external evaluator to that of a principal investigator of the REU site. The REU administrator and their team then has the option to develop new evaluation tools or modify existing evaluation tools that can be provided by colleagues within their discipline or larger groups. Two popular sources for survey items available to REU administrators include the University of North Charlotte CISE REU Toolkit[2] or the Undergraduate Research Student Self-Assessment (URSSA)[3]. For example, URSSA includes survey items that assess gains of skills, research experience, students' research experience (activities, time with mentors, etc.) and career goals.[3]

This paper summarizes key steps of administrating REU sites (recruiting of participants, etc.) and also reports on the development of surveys to track changes to research self-efficacy that participants experience during 10-week research experiences. It also highlights best practices that emerged from participant exit interviews. The data was collected at a southeastern REU site, which had stated goals of assembling and providing a diverse group of undergraduate participants with the opportunity to conduct research and engage in professional development workshops. These goals are similar to those posted by almost all REU sites.

Recruiting Participants into REU Programs

The process of contacting potential student participants typically includes a combination of methods, including: advertising the program through professional societies' listservs, contacting collaborators who advise undergraduate students, and conducting campus visits to regional four-year institutions. Recruiting materials provided to applicants normally include both programmatic information (stipend amount, length of program, date of program start, etc.) and information on the research experience (projects, scopes, mentors, etc.). A prior study of REU applicants showed that the students considered the focus of the research project, the stipend or compensation, and the date they receive their acceptance and offer as primary factors when making their program selection.[4,5] Since the offer date is dependent on the faculty administrator's selection timeframe, the date of material distribution and the due-date of the applications are also important to assembling a diverse cohort of participants.

Faculty Advisors Recruitment for REU Sites

The methods by which administrators recruit faculty advisors to mentor the REU participants is more divergent between REU sites. For the REU site referenced within this paper, the faculty administrator contacted potential faculty advisors to request that they submit a short description of an undergraduate research project early in the fall term. At the same time, the potential faculty advisors would be asked to indicate if the REU participant would be paired with graduate student mentor. The number of faculty members contacted was greater than the number of anticipated REU participants, since some of the faculty advisors would have time conflicts preventing participation (e.g. sabbaticals, summer travel for conferences, and other research commitments). Once the faculty advisors committed, their research projects were uploaded to the application site. This allowed the student applicants to make informed selections for project preferences when applying. During the offer process, the REU applicant was offered a position to work on a specific project, and not just a general offer to participate within the program. Before the official start of the program, the faculty administrator hosted a training session for the faculty advisors, and associated graduate student mentors, to learn the importance of mentoring, communication skills, and other tips-and-tricks. During this session, the faculty advisors were reminded that the REU participants would be required to take part in a majority of the professional development workshops provided by the REU.

Introduction to Research Self-Efficacy

Self-efficacy refers to individuals' beliefs that they can produce desired results, whether the desired results are imposed by themselves, or set as expectations.[6] Albert Bandura developed the theory of self-efficacy, which has shown across numerous studies that people's beliefs about what they can and cannot do are strong predictors of their subsequent behavior.[7] Bandura proposed that self-efficacy is informed by four sources: mastery experiences, vicarious experiences, social persuasion and induction of positive physiological responses. Extrapolating from Bandura's work, mastery experience (participating in research) should lead to improvements in students' beliefs that they can succeed in a research setting (research self-efficacy).

Prior studies have sought to understand how research self-efficacy impacts the outcomes of undergraduate research experiences using self-report surveys. Respondents make their level of endorsement to a series of closed-ended statements that typically involve a perception of capability in the form of "I have the ability to…", "I believe I can…", and "I feel comfortable doing…" Our study builds upon Adedokun et al.'s research self-efficacy scale development[8] for a undergraduate research experience during the academic year. In their study, a post program survey was used to probe participant 's abilities/confidence in research. Their results indicated direct relationships between research skills and research self-efficacy. These researchers also found that research skills and self-efficacy were good predictors of career aspirations.[8] However, the measures used to assess research self-efficacy were not ideal. For example, items such as "I have the ability to have a successful career as a researcher," and "I have a strong interest in pursuing a career as a researcher" are reflective of the student's career goals, but may not reflect their beliefs in their current research capabilities. This concern about the quality of self-efficacy items for assessing the gains in REU programs was highlighted earlier by Chris Aberson and Jenna Barry in their report, "REU Program Evaluation Instrument Phase II: Instrument Recommendations".[9] In that report, they made suggestions as to which self-efficacy items might be used for undergraduate research experiences. These items were later shared through the toolkit for REU administrators assembled by the University of North Carolina Charlotte Research Experience for Undergraduates: Socially Relevant Computing (http://reu.uncc.edu/toolkit/analysis, Audrey Rorrer).

The current study looked at further adapting items from these prior reports, and creating new items when needed, to better understand gains in research self-efficacy during participation in summer REU sites. While developing our items, we also looked at qualitative studies, such as that by Trenor and Pierrakos[10], that examined students' self-efficacy for future research and consulted with REU administrators.

Assessing Research Self-Efficacy

The Likert-type scale used in this study was a six-item scale to ensure students would not over-rely on a neutral response category and to provide enough options so that the participants could rate their capabilities in sufficiently nuanced ways. Each response was then coded so that "strongly disagree" equaled "1" up to "strongly agree" having a value of "6". Participants responded to these items both during the first week of the program (Time Point 1, TP1) and also at the end of the program (Time Point 2, TP2).

We initially developed 12 items to assess participants' perceived capabilities to successfully complete various research-related tasks (i.e., research self-efficacy) in the first summer of a research program. These items were provided to the first cohort of students (n = 9). Evaluation of the participant responses and feedback from the program external evaluator were then used to improve the self-efficacy scale by refining and adding new items. This altered scale was then given to the second cohort of participants (n = 11). This research self-efficacy scale will be further refined as data are gathered across seven summer REU sites. In order to provide more rigorous evidence of the items' validation, we would have need approximately 300 participants.

Analysis of Cohort 1 Responses to Self-Efficacy Items

Student's responses to self-efficacy scales were assessed at the item level (e.g., examining mean scores across participants' ratings for each item). A paired sample t-test was then performed on the participants' mean scores at TP1 and TP2. Results, including the two-tailed p value, is included in Table 1. The cohort's self-efficacy ratings at TP1 and TP2 were statistically significant for seven questions (p value < 0.05) and this was denoted by an asterisk in Table 1. Since the mean pre-assessment research self-efficacy scores were lower than the post-assessment scores (only seven were significantly so), the students felt more confident in their research ability at the end of the REU experience. The largest gains in self-efficacy across the program were for conducting literature reviews, identifying opportunities for external funding (scholarships and fellowships), applying to graduate school, and communicating scientific findings through oral presentation. In addition, the effect size (Cohen's d)[11,12] was calculated for each item (Table 1). This indicates the practical significance of changes for each item between TP1 and TP2. These values show that there was not significant overlap between the TP1 and TP2 responses except for

Item 1 ("document my research in a laboratory notebook") and Item 2 ("steps to patent research"). Focus group interviews conducted by the evaluator confirmed these survey findings and pointed to specific REU programming that boosted students' self-efficacy in these areas.

Table 1: Mean values of Likert scale responses to self-efficacy items by Cohort 1. These self-efficacy items were developed by the authors, or were modifications of items published elsewhere.[9,13,14]

Item Number	Item	Item Source	Participants Responding (*n*)	TP1 Mean	TP1 STD	TP2 Mean	TP2 STD	*p*		Cohen's *d*
1	I can document my research in a laboratory notebook.		9	5.78	0.44	5.89	0.33	0.3466		0.28
2	I can identify the steps to patent research.		9	3.78	1.09	3.89	1.17	0.7995		0.10
3	I can perform experiments independently.	Mamaril (2016), adapted from Schreuders (2009)	9	4.89	0.60	5.56	0.53	0.0497	*	1.18
4	I can analyze data resulting from experiments.	modified from Aberson (2009)	9	5.13	1.13	5.75	0.46	0.0492	*	0.73
5	I can find journal papers related to my research project.	modified from Aberson (2009)	8	5.33	0.87	6.00	0.00	0.0497	*	1.09
6	I can perform a literature review.	modified from Aberson (2009)	9	4.11	1.36	5.44	1.01	0.0039	*	1.11
7	I can identify scholarship and fellowship opportunities for graduate programs in science or engineering.		9	4.44	1.13	5.44	0.73	0.0278	*	1.05
8	I can communicate the results of a research project in written form.	modified from Aberson (2009)	9	5.00	1.12	5.44	0.53	0.2721		0.51
9	I can communicate the results of a research project in an oral presentation.	modified from Aberson (2009)	9	4.89	1.36	5.67	0.50	0.0653		0.76
10	I can communicate the results of a research project in a poster.	modified from Aberson (2009)	9	5.00	1.12	5.67	0.50	0.0497	*	0.77
11	I can orally communicate the results of experiments.	modified from Aberson (2009)	9	5.00	1.32	5.67	0.50	0.1114		0.67
12	I can identify how to apply to graduate school in engineering or science.		9	4.78	0.67	5.67	0.71	0.0092	*	1.29

Analysis of Cohort 2 Responses to Self-Efficacy Items

Based on the initial findings from Cohort 1, and through comparison of our scale with other research self-efficacy scales previously published or used for internal studies (Dr. K. Findley, Colorado School of Mines), we further improved the scale. We modified the survey to include items that more clearly communicated the research context. For example, we now utilize the item "I can document my research in a laboratory notebook" instead of "I can document my work within a laboratory notebook". We also changed the item "I can perform a literature review" to "I am comfortable with reviewing papers relevant to my research" to ensure that "literature review" is not being confused with English literature or general scientific literature. The modified items are shown in Table 2.

Analysis of the responses of Cohort 2 showed that the mean pre-assessment research self-efficacy scores were lower than the post-assessment scores. Statistical tests showed that the mean scores for 13 items were statistically higher at TP2 (Table 2). Cohen's *d* showed that there was not significant overlap between the TP1 and TP2 responses except for item 5 ("I can find journal papers related to my research project").

Table 2: Mean values of Likert scale responses to self-efficacy items by Cohort 2.

Item Number	**Item**	**Changes/ Item Source**	**Participants Responding (*n*)**	**TP1 Mean**	**TP1 STD**	**TP2 Mean**	**TP2 STD**	***p***		**Cohen's *d***
1b	I can document my research in a research laboratory notebook.	modified	11	5.00	0.77	5.82	0.40	0.0011	*	1.32
2b	I can identify the steps to patent research findings.	modified	11	2.91	1.45	4.36	1.21	0.0145	*	1.09
3b	I can perform research experiments independently.	modified	11	4.55	1.04	5.45	0.52	0.0016	*	1.11
4b	I can analyze data resulting from research experiments.	modified	11	4.82	0.87	5.36	0.67	0.0816		0.70
5	I can find journal papers related to my research project.		11	5.55	0.82	5.73	0.65	0.4405		0.25
6b	I can perform a literature review on prior research in my field.	modified	11	4.64	1.43	5.64	0.92	0.0187	*	0.83
7	I can identify scholarship and fellowship opportunities for graduate programs in science or engineering.		11	4.27	1.27	5.64	0.67	0.0077	*	1.34
8	I can communicate the results of a research project in written form.		11	5.09	0.83	5.64	0.50	0.0519		0.79
9	I can communicate the results of a research project in an oral presentation.		11	5.09	0.83	5.64	0.67	0.0061	*	0.72
10	I can communicate the results of a research project in an poster.		11	5.27	0.79	5.82	0.40	0.0519		0.87
11	I can orally communicate the results of experiments.		11	5.09	0.83	5.82	0.40	0.0119	*	1.11
12	I can identify how to apply to graduate school in engineering or science.		11	4.27	1.27	5.64	0.67	0.0038	*	1.34
13	I can collect data from experiments.	modified item from Aberson 2009	11	5.27	0.65	5.82	0.40	0.0251	*	1.01
14	I can develop research methodology to address my research topic.	Findley 2015 Internal Report	11	4.73	0.90	5.27	0.79	0.1399		0.64
15	I can formulate a hypothesis or objective for a research project.	modified item from Aberson 2009	11	4.55	0.69	5.64	0.50	0.0014	*	1.81
16	I have the ability to have a successful career as a researcher.	added	11	4.64	0.81	5.27	0.90	0.0455	*	0.74
17	I can discuss research at a professional meeting or conference.	item from Aberson 2009	11	4.73	0.79	5.45	0.82	0.0236	*	0.91
18	I can discuss research with professors.	item from Aberson 2009	11	5.45	0.69	5.64	0.50	0.3409		0.30
19	I can discuss research with graduate students.	item from Aberson 2009	11	5.55	0.69	5.73	0.47	0.3409		0.31
20	I can discuss research with other undergraduate students.	modified item from Aberson 2009	11	5.73	0.47	5.91	0.30	0.1669		0.46
21	I can work with others to investigate a research project.	item from Aberson 2009	11	5.64	0.67	6.00	0.00	0.1039		0.76
22	I can statistically analyze data.	item from Aberson 2009	11	4.55	1.13	5.18	0.87	0.0669		0.63
23	I can design an experimental test of a solution to a research problem.	modified item from Aberson 2009	11	4.36	1.12	5.09	0.83	0.0236	*	0.74

Insight from comparison of Self-Efficacy Responses to Additional Data

It should be noted that many of the activities that participants take part in during the summer REU program had been experienced by them before. Table 3 summarizes examples of activities that the students have experienced prior to arriving onsite during Cohort 2. It shows that 10 out of the 11 participants had experience finding and reading journal articles for research prior to arrival. However, these REU participants highlighted in open-ended responses that programming related to reading journal articles strengthened their skills. Participant 1 noted ,

> *"The talks regarding reading research papers were particularly useful as the 10 weeks went on. I was reading a lot more than I used to read back at my university and all those tips were quite helpful."*

Another wrote

> *"I think the 'best practices for reading literature' seminar was really helpful because it helped expose me to some new techniques and resources I had never used. I now prefer webofknowledge.com to google scholar."*

Table 3: Before coming to the REU site, the participants have previously completed many of the research activities. This table shows the frequency of exposure for the participants in the second cohort (*n* = 11).

Which of the following things have you previously done before coming to the REU program? Select all that apply.	
Discussed research with other undergraduate students.	11
Found journal papers related to a research project.	10
Discussed research with professors.	10
Read engineering and science research literature (e.g. journal articles).	10
Perform research experiments	9
Collected data from experiments.	9
Analyzed data from research experiments.	9
Wrote a report about your research results from a project.	8
Used research laboratory notebook.	7
Gave an oral presentation on your own research project.	7
Worked with a team on a research project.	7
Statistically analyzed data.	6
Designed the steps in a research project.	5
Identified a hypothesis or objective for a research project.	5
Presented a research poster.	5
Discussed research with graduate students.	5
Identified scholarship and fellowship opportunities for graduate programs in science or engineering.	4
Discussed research at a professional meeting or conference.	2
Designed experimental test of a solution to a research problem.	2
Filed a patent.	0

Future Work and Reflections on Best Practices

REU programs have the ability to positively impact the research self-efficacy of students within STEM undergraduate programs. While more work needs to be done to examine how the quality of programming influence the student experience and their research self-efficacy, the authors also acknowledge that there is a lack of information on how to administer programs in the literature. Reflecting this work and from conversations with program administrators at multiple REU sites, three best practices emerged:

- Program administrators should provide mentoring for research skills or activities that students have already experienced on their home campus. Revisiting skills such as journal article analysis and laboratory notebook maintenance will allow students to sharpen their skills and gain confidence.
- While most students have worked with faculty prior to coming to an REU, few of these students have worked directly with a graduate student. By planning for a graduate student mentor in addition to a faculty mentor, the REU student will have the opportunity to learn more about the process to apply to graduate school and to 'see' what it is like to be a graduate student.
- An orientation for faculty advisors and graduate mentors should be implemented. These meetings allowed the program manager to remind the faculty and graduate students that the purpose of the program was to provide opportunities to conduct research, increase student's technical content knowledge, and also provide students with the knowledge, skills and social networks to decrease barriers when appling to graduate school. Graduate students were encouraged to talk to students informally about their experiences applying to graduate programs and their own experiences within their graduate program.

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References

1. Russell SH, Hancock MP, McCullough J. Benefits of undergraduate research experiences. *Science(Washington)*. 2007;316(5824):548-549.
2. Rorrer AS. An evaluation capacity building toolkit for principal investigators of undergraduate research experiences: A demonstration of transforming theory into practice. *Eval Program Plann*. 2016;55:103-111. doi:https://doi.org/10.1016/j.evalprogplan.2015.12.006.
3. Hunter A, Weston TJ, Laursen SL, Thiry H. Undergraduate Research Student Self-Assessment (URSSA). 2009.
4. Economy DR, Martin JP, Kennedy MS. Factors influencing participants' selection of individual REU sites. In: *Frontiers in Education Conference, 2013 IEEE*. IEEE; 2013:1257-1259.
5. Economy DR, Sharp JL, Martin JP, Kennedy MS. Factors Associated With Student Decision-Making for Participation in the Research Experiences for Undergraduates Program. *Int J Eng Educ*. 2014;30(6):1395-1404.

6. Bandura A. *In Self-Efficacy; Encyclopedia of Human Behavior*. New York: Academic Press; 1994.
7. Richardson M, Abraham C, Bond R. Psychological correlates of university students' academic performance: a systematic review and meta-analysis. *Psychol Bull*. 2012;138(3):353–387.
8. Adedokun OA, Bessenbacher AB, Parker LC, Kirkham LL, Burgess WD. Research skills and STEM undergraduate research students' aspirations for research careers: Mediating effects of research self-efficacy. *J Res Sci Teach*. 2013;50(8file:///Users/mskenne/Downloads/PhysRevPhysEducRes.12.020140(1).bibtex):940-951. doi:10.1002/tea.21102.
9. Aberson C, Barry J. REU Program Evaluation Instrument Phase II: Instrument Recommendations. 2009.
10. Pierrakos O, Trenor J. Using a mixed-mthods approach to investigate students' perceived learnign and challenges faced during a summer undergraduate research experience. In: *American Society for Engineering Education*.Vol 14.; 2009:AC 2009-744:
11. Cohen J. The effect size index: d. *Stat power Anal Behav Sci*. 1988;2:284-288.
12. Thalheimer W, Cook S. How to calculate effect sizes from published research: A simplified methodology. *Work Res*. 2002:1-9.
13. Mamaril NA, Usher EL, Li CR, Economy DR, Kennedy MS. Measuring Undergraduate Students' Engineering Self‐Efficacy: A Validation Study. *J Eng Educ*. 2016;2(105):366-395.
14. Schreuders PD, Mannon SE, Rutherford B. Pipeline or personal preference: Women in engineering. *Eur J Eng Educ*. 2009;34(1):97-112.