New Orleans JAZZED about Engineering Education

Paper ID #15316

Examining Student Outcomes from a Research Experiences for Undergraduates (REU) Program: Year Two Results

D. Jake Follmer, The Pennsylvania State University - University Park

D. Jake Follmer is a doctoral candidate in educational psychology at The Pennsylvania State University. His interests are in issues related to learning, assessment, and program evaluation.

Dr. Sarah E. Zappe, The Pennsylvania State University - University Park

Dr. Sarah Zappe is Research Associate and Director of Assessment and Instructional Support in the Leonhard Center for the Enhancement of Engineering Education at Penn State. She holds a doctoral degree in educational psychology emphasizing applied measurement and testing. In her position, Sarah is responsible for developing instructional support programs for faculty, providing evaluation support for educational proposals and projects, and working with faculty to publish educational research. Her research interests primarily involve creativity, innovation, and entrepreneurship education.

Dr. Esther Gomez, The Pennsylvania State University - University Park

Dr. Esther Gomez is an assistant professor in the Departments of Chemical Engineering and Biomedical Engineering at the Pennsylvania State University. Dr. Gomez's research focuses on exploring how the interplay of chemical and mechanical signals regulates cell behavior and function and the progression of disease. She is also the Co-Director of a National Science Foundation sponsored Research Experience for Undergraduates program focused on the Integration of Biology and Materials in Chemical Engineering.

Dr. Manish Kumar, The Pennsylvania State University

Manish Kumar is an Assistant Professor of Chemical Engineering and a current co-Director of the Penn State REU on "Integration of Biology and Materials in Chemical Engineering". He obtained his PhD in Environmental Engineering at the University of Illinois at Urbana Champaign and conducted postdoctoral research at the Harvard Medical School. He has 7 years of industrial research experience in environmental consulting and is dedicated to training young professionals.

Examining Student Outcomes from a Research Experiences for Undergraduates (REU) Program: Year Two Results

Abstract

The importance of undergraduate research experiences in facilitating students' research-based skills and development has been supported in numerous studies[1-4]. The current study presents a follow-up, second-year evaluation of an in-progress research experiences for undergraduates (REU) program, funded by the National Science Foundation, which focuses on the integration of biology and materials. Participating students (*N*=13; 39% female; 54% underrepresented minority status) completed measures of research-based skills and experience, likelihood of pursuing graduate school, and openness to collaborating with others both prior to and after completion of the ten week REU program. Participants also completed in-depth interviews as well as measures of REU program satisfaction and ratings of REU program elements after completing the REU.

Students demonstrated significant gains in measures of research experience and specific research-based skills. Students also rated themselves as open to collaborating with other students and faculty during research both before and after completing the program. Ratings of program elements indicated positive ratings of the working relationship with research mentors, the working relationship with research group members, the amount of time spent with research mentors, and the advice given about graduate school. Improvement was suggested for the element of amount of time spent doing meaningful research. REU program participants indicated anticipated completion of a presentation, talk, or poster at a professional conference (25%) and involvement in co-writing a paper for either an academic journal or an undergraduate research journal (33%). Approximately 58% of participants indicated plans for some level of graduate school at program completion.

Interviews of program participants corroborated the indication of research-based gains and provided a more in-depth understanding of impact of the program. Specifically, interviews provided information about participants' interests in pursuing the program, perceptions of the effectiveness of specific program elements, and suggestions for improvement. Implications for the development of research programs for undergraduate students are discussed.

Introduction

The current study reports the results of an evaluation of student experiences and gains from participation in the second year of a research experiences for undergraduates (REU) program. The program emphasized and supported student collaboration as a mechanism for fostering integration and the development of meaningful research experiences among participating undergraduate students. During the ten week program, students collaborated with other undergraduate researchers from the host institution as well as graduate students and faculty mentors. Students also participated in professional development seminars and structured social activities designed to further facilitate cohesion and integration into the research setting. The findings support the use of effective structural and programmatic elements in implementing research programs aimed at fostering research skills among undergraduate students. The findings also contribute to a developing understanding in the literature of the benefits of REU programs as well as the importance of student collaboration during structured research as a mechanism for fostering the development of research skills [1-4].

Background

The importance of undergraduate research experiences in facilitating students' research-based skills and development has been supported in numerous studies [1-4]. REU programs in particular have been shown to support participating students' involvement in research experiences and projects, exposure to a simulated graduate school environment, and development of research-based skills [5-7]. REU programs have also been shown to provide a refining experience in terms of students' beliefs and goals regarding the pursuance of graduate education [1]. Seymour and colleagues, for example, reviewed published studies and proceedings examining the impact of undergraduate research experiences and found that such experiences provided benefits in several areas [8]. These included increases in research interest in specific research areas, a greater presence of underrepresented students in research-based experiences, and clarification or refinement of educational and career goals, as examples [1, 8].

In an evaluation of an REU program, Bielefeldt observed significant gains in several key skill areas, including knowledge of research and graduate student funding, knowledge of research design, and knowledge of research methods [2]. Students who had limited experience with research prior to participation in the REU program evidenced greater gains in skill development in areas related to research [2]. Similarly, in prior research, Lopatto found evidence of several benefits of undergraduate research, including improved understanding of the research process, facility with laboratory and related techniques, and enhancement of students' overall undergraduate educational experience [9]. Such research supports the ability of REU programs to foster development in research experiences among undergraduate students in general and underrepresented students in particular.

The current REU program emphasized the integration of biology and materials and included research that incorporated materials produced using biological systems, materials that incorporated one or more biological components, or materials that mimicked biological structures [1]. The primary objectives of the REU program were to enhance the diversity of students participating in chemical engineering research, provide career- and graduate school-

based opportunities and experiences, develop experience and skills related to laboratory- and simulation-based research, and foster the development of research communication skills. A more detailed description of the REU program structure, objectives, and elements is included in prior work evaluating initial student outcomes from the program [1].

The current study presents a follow-up, second-year evaluation of a research experiences for undergraduates (REU) program that is currently in progress, funded by the National Science Foundation and focused on the integration of biology and materials. As in the first year of the program, participating students completed measures of research-based skills and experience, likelihood of pursuing graduate school, and openness to collaborating with others both prior to and after completion of the 10-week REU program. Participants also completed in-depth interviews as well as measures of REU program satisfaction and ratings of REU program elements after completing the REU. The primary research questions targeted 1) whether gains were observed in research-based skills among students participating in the second year of the program; 2) whether initial evidence of involvement in research activities (i.e., presentations at conferences, publication of research findings, etc.) was obtained; and 3) whether evidence of student satisfaction with the program was obtained.

Student Participants

Demographic information for participants during the second year of the REU program is included in Table 1. As in the evaluation of year one of the REU program, the percentage of students participating in the REU program who were female and were from underrepresented groups exceeded the typical representation of such students at the undergraduate level in engineering [10]. No students reported prior experience with REU programs. Differences in scores on the post-survey were examined descriptively based on student gender and ethnicity. Student scores on the post-survey measures were similar across gender and ethnicity.

Table 1. Demographic Information of NSF-Funded REU Participants

Year	Number of Participants	% Past REU Experience	% Female	% URM	% Fr/So/Ju/Se
2015	13	0	39	54	0/23/46/31

Note. URM = Under-Represented Minority; Fr = Freshmen; So = Sophomore; Ju = Junior; Se = Senior.

Assessment Methodology and Measures

The assessment methodology employed in this study followed a similar methodology used in prior evaluation of the REU program [1]. Pre- and post-surveys were administered at the beginning (week 1) and end (week 10) of the REU program, respectively. Table 2 describes the scales, number of items, and scale anchors for each of the measures. The surveys included two measures of research-based experience: the Experiences with Research Activities Scale (EWRAS) and the Undergraduate Research Student Self-Assessment (URSSA).

The EWRAS is a brief, 4-item scale that measures broad research experience. The EWRAS was designed for the evaluation of this REU program [1]. It measures student ratings of experience based on the following elements: experience with research, experience working in a research lab,

experience collaborating with faculty while engaged in research, and experience working with students while engaged with research.

The URSSA is a 37-item, NSF-funded survey instrument designed to measure student learning gains from research experiences [11]. The URSSA was designed to assess student outcomes from structured research experiences such as REU programs and has been used in prior research to examine such gains. The URSSA assesses student ratings of skills related to lab work, communication of research findings, conceptual knowledge and linkages, and an increased understanding of the intellectual and practical work of science, as examples [1, 11]. Evidence supporting the validity of score interpretations as well as the reliability of scores on both the EWRAS and the URSSA has been obtained in prior research [1, 12].

Table 2. Description of Pre- and Post-Survey Measures

Measure	# of Items	Scale Type	Scale Anchors/Response Type
URSSA	37	6-Point Likert	Not at all confident – Very confident
EWRAS	4	5-Point Likert	Not experienced – Very experienced
Openness to collaborating	1	5-Point Likert	Not open – Very open
Likelihood of grad school	1	5-Point Likert	Very unlikely –Very likely

The post-surveys also included items measuring students' ratings of REU program elements and satisfaction with the REU program overall. Ratings were provided for areas such as time spent doing research, advice given by research mentors, and relationships with research group members. Engagement with research activities was measured by having participants indicate participation in or anticipated completion of the following activities based on research conducted during the REU: presenting a talk or poster to other students or faculty, presenting a talk or poster at a professional research conference, writing or co-writing a paper to be published in an academic journal, and winning an award or scholarship based on research completed during the REU program. All measures were administered electronically using survey software.

Student and faculty interviews were conducted during the last weeks of the REU program (weeks 8-10). The student interviews provided a more in-depth and qualitative assessment of REU program elements, including research-based and project-based experiences, perceived benefits of participation in the program, perceived impact of the REU on career and/or educational goals, and suggestions for improvement to the REU program. The faculty interviews provided assessment of processes employed for acclimating students to the research projects, perceived changes in students' research skill levels, benefits to collaborating during the REU program, and suggestions for improvement. Approval from the Institutional Review Board was obtained prior to data collection; implied and informed consent were obtained prior to data collection for all measures.

Results

Data were analyzed using IBM SPSS, Version 23. Table 3 presents descriptive and reliability statistics for pre-survey measures. Scores on the EWRAS and URSSA demonstrated adequate reliability.

Table 3. Descriptive Statistics for Pre-Survey Measures

Measure	*Mean*	*Median*	*Standard Deviation*	Range	Minimum-Maximum	α
URSSA	151.86	150.00	26.71	82.00	112.00-194.00	.96
EWRAS	10.07	10.00	4.10	14.00	4.00-18.00	.79
Openness to collaborating	4.57	5.00	0.85	3.00	2.00-5.00	N/C
Likelihood of grad school	4.00	4.00	1.04	3.00	2.00-5.00	N/C

Note. URSSA=Undergraduate Research Student Self-Assessment; EWRAS=Experiences with Research Activities Scale. Minimum-Maximum=minimum and maximum scores obtained for each of the measures. α=Cronbach's alpha. N/C=Not calculable because there was one score per measure.

Table 4 presents descriptive and reliability statistics for post-survey measures. Scores on the measures again demonstrated adequate reliability. Increases in scores on the EWRAS and URRSA were observed. Data on the post-survey measures were obtained from 11 REU participants, reflecting an 85% post-survey completion rate.

Table 4. Descriptive Statistics for Post-Survey Measures

Measure	*Mean*	*Median*	*Standard Deviation*	Range	Minimum-Maximum	α
URSSA	180.42	176.50	18.27	60.00	153.00-213.00	.91
EWRAS	15.83	16.00	2.44	7.00	13.00-20.00	.86
Openness to collaborating	4.67	5.00	0.65	2.00	3.00-5.00	N/C
Likelihood of grad school	4.17	4.50	1.03	3.00	2.00-5.00	N/C

Note. URSSA=Undergraduate Research Student Self-Assessment; EWRAS=Experiences with Research Activities Scale. Minimum-Maximum=minimum and maximum scores obtained for each of the measures. α=Cronbach's alpha. N/C=Not calculable because there was one score per measure.

Examination of Student Gains and Ratings of the REU Program

Students who participated in the REU program demonstrated significant gains in reported research experience as measured by the EWRAS, F (1, 10) = 15.16, $p < .05$, $\eta_p^2 = .60$. A significant gain in students' URSSA scores was also obtained, F (1, 10) = 13.92, $p < .05$, $\eta_p^2 = .58$, indicating increases in specific research-based experiences among students. Descriptively, students demonstrated an increase from pre-survey to post-survey in mean scores on the EWRAS from 11.09 to 15.82 and from 152.00 to 181.00 on the URSSA. Students' reported research experience on the EWRAS and URSSA were significantly correlated, $r = .65$, $p < .05$, suggesting a strong relationship between the development of broad and specific research skills at program completion. Taken together, the findings indicated significant gains in both broad research experience and specific research skills among students participating in the REU program.

Table 5 lists mean and mode responses for ratings of key REU program elements. Ratings of REU program elements were measured using a 4-point Likert scale (1 – Poor to 4 – Very good). Analysis of program ratings revealed overall satisfaction with the REU program (M = 4.17; Mo = 4). Ratings of "Good" or higher, as evidenced by mean and mode responses, were obtained for the following REU elements: working relationship with research mentor(s) (M = 3.17; Mo = 4); working relationship with research group members (M = 3.75; Mo = 4); the amount of time spent with research mentor(s) (M = 2.83; Mo = 4); the advice given about careers and graduate school

(*M* = 3.45; *Mo* = 3); and the research experience overall (*M* = 3.25; *Mo* = 3). The REU element of the amount of time spent doing meaningful research received a "Fair" rating overall (*M* = 2.83; *Mo* = 2), suggesting an important area of improvement for the research program.

Table 5. Mean and Mode Responses for Ratings of REU Elements

Item	*Mean*	*Mode*	*Standard Deviation*
Relationship with mentor	3.17	4	1.03
Relationship with research group	3.75	4	0.62
Time spent doing research	2.83	2	0.94
Time spent with mentor	2.83	4	1.27
Advice given by mentor	3.45	3	0.52
Research experience overall	3.25	3	0.62

In terms of engagement in research activities, approximately 25% of students indicated completion of a presentation, talk, or poster at a professional conference. Similarly, approximately 33% of students indicated involvement in co-writing a paper for either an academic journal or an undergraduate research journal. With respect to career and educational goals, approximately 8% of NSF-funded REU students indicated plans for pursuing a master's degree, while 50% of students indicated plans for pursuing a doctoral degree. Thus, approximately 58% of participants indicated plans for some level of graduate school after graduation. Finally, approximately 33% of students expressed plans for pursuing a career in engineering; one student indicated plans for pursuing medical school.

Student Interviews

As in the preliminary evaluation of the program, all students were interviewed by the first author. The interviews lasted approximately twenty to thirty minutes in length. Informed consent was obtained prior to each interview. Interviews were recorded and transcribed for analysis. The interviews were then analyzed using NVivo 10, a computer software package designed for qualitative analysis of interviews and related information [13]. Interviews were coded using a general inductive qualitative approach based on the derivation of coding themes created from analysis of student interviews during year one of the program [1, 14]. Codes were refined in an iterative process as additional quotes and examples of the codes emerged. This process yielded themes based on: students' motivations for participating in the program; students' experiences with research mentors; students' perceived gains from participation in the program; students' beliefs about the impact of the REU program on their career- and education-related goals; and students' suggestions for improvement to the program.

Students' motivations for participating in the REU program centered on a desire for exposure to research as well as an environment that approximated a graduate school environment, a desire to gain lab-based experience, and using the program as a way of determining the appropriateness and fit of graduate school. For example, one student indicated "I'm looking at grad school after I graduate, and I thought this would just be a really good program to get a taste of what grad school would be like, get research experience." Some students noted the perceived importance of the program given the relative lack of opportunities for conducting undergraduate research at their home institutions. For example, one student indicated "So at my college, there aren't many opportunities to participate in undergraduate research. So participating in the REU gave me an

opportunity to participate in research outside my institution, and also, it allowed me to go into the chemical engineering research area which at [student's institution] is very hard to get into."

Students' experiences with their research mentors were largely positive. Students noted several benefits from working with either faculty or graduate student mentors. These included help and training in conducting procedures in laboratory or computational settings, advice about graduate school and expectations for the requirements and nature of graduate education, and practice reading, discussion, and presenting research. Several students, however, discussed issues regarding differences in preferences for structure and scheduling between them and their research mentors. One student, for example, noted a preference for established working hours which did not conform to the variable structure and work of the lab in which she was working. This perceived mismatch as a result in differences in preference for structure and the nature of the work she was completing contributed to perceptions of a lack of organization within the lab setting and of the program as a whole.

In terms of perceived gains as a result of completing the REU program, students' discussions centered on gains in laboratory or computational experience, an increased understanding of research and the processes involved in research, and an improved understanding of what a graduate school experience entails. One student commented, "I've gained a better understanding of what research is and how to go about it and just the process of doing it and seeing how people interact together in the lab." Other students characterized the REU program as a refining experience, one that allowed them to better sort out what they did and did not want to pursue after their undergraduate education. As one student mentioned, "I definitely gained the type of person that I know I want to be in the future, so I know I definitely want to work in industry unless I find that specific topic." Points such as these highlight the importance of REU programs in providing a backdrop against which to evaluate the relative fit of graduate education and related experiences.

Related to this finding were findings regarding the perceived impact of the REU program on students' career- and education-related goals. Student responses varied based on their expressed interests regarding pursuing industry vs. graduate education. The majority of students indicated that the program served to bolster their interests in pursuing graduate school by providing an authentic research experience. As one student who is interested in pursuing graduate school discussed, "...it introduced me to what the world of research is like at a graduate institution. So it's definitely helped me learn what's expected, what sorts of tests you have to perform, what sort of boundaries there are, what sort of limitations you have with time and resources and things like that." Another student who came into the program interested predominantly in pursuing a career in industry commented that "...before coming here, I had plans of doing something in industry, and I was open-minded because I had been exposed to research before, but it was just data analysis and very basic things like on-line research and just number crunching." Students such as this one used the experience to strengthen their prior interests and goals, again highlighting an important refining function of the REU program for select students.

Finally, student interviews provided key information about suggestions for improvement to the implementation of the REU program. Primary suggestions for improvement among participating students centered on improved communication among faculty mentors, graduate student mentors,

and student participants as well as improved organization and structure of key REU program elements. Both of these suggestions indicated perceived benefit of earlier communication about the REU program structure, requirements, and expectations so as to facilitate the progress of the research experience from the outset. Some students commented on the fast-paced nature of the REU program as well as the relatively limited timeframe within which to complete research projects as a basis for ideas about improved structure. These ideas are demonstrated by the following, "It would be beneficial if you can get a lot of the reading before you get there, because once you get here, you jump straight into experiments, plus you have the background reading to do, and you've got to catch up to the other research students." These points highlight an important need for clearer communication of the structural components of the research program that work to facilitate progress in and completion of the program. Other students expressed a desire for additional activities, including social outings for example, that could facilitate developing a sense of community among the students and research mentors.

Research Mentor Interviews

As a way of assessing student progress during the course of the REU program from the perspectives of the research mentors, interviews were also conducted with either the faculty members or the graduate students who most closely worked with and mentored the students throughout the course of the program. Interviews with the research mentors ($N = 8$) were conducted by the first author; informed consent was obtained prior to conducting each interview. A similar coding procedure was employed with the research mentor interviews [13]. Interviews were coded based on themes generated during evaluation of year one of the program and were refined as needed during the coding process [1, 13]. Analysis of the interview data yielded themes based on: perceived changes in REU students' skill levels; experiences working with and mentoring students; perceived benefits in working with and mentoring students; and suggestions for improvement to the REU program.

Perceived changes in students' skill levels centered on increases in students' lab-based experience and analytical skills, independence in conducting research procedures, and understanding of the processes of and difficulties associated with research. Mentors also discussed students' increased use of and reliance on prior empirical research to guide decision making and communication of research procedures and results during the course of the REU program. Other mentors commented on students' improved ability with statistical analyses on data collected during the program.

In terms of mentors' experiences working with student participants, the primary concern expressed was the ability to find an appropriate balance of providing adequate and meaningful experiences to students that were manageable given students' developing skill levels. As one mentor indicated, "the initial challenge for the younger student was deciding how much autonomy to give her or what to assign to her." This need for balancing provided experiences with skill level often necessitated clear and effective mentoring from the outset of the program. Perceived benefits as a result of hosting and mentoring REU students largely reflected the ability to complete more lab-based or computational work during the course of the program. Related to this was an opportunity for graduate students to develop key experience mentoring and teaching

undergraduate students in a research program context – an opportunity that might not otherwise exist outside of the structure of the REU program.

Suggestions for improvement to the REU program reflected in part those raised by students during the student interviews. A need for additional or improved faculty involvement was expressed by several participating research mentors. This involvement extended into elements such as increased exposure via meeting times (i.e., in terms of frequency and with respect to scheduling weekly) and structured presentations of faculty research to participating students at program outset. Similarly, a need for improved organization and structure – as well as the communication of that structure to participating students – was also expressed by research mentors.

Summary and Implications

The current study presented findings from an evaluation of an REU program that is currently in progress. These findings build on those obtained in the preliminary evaluation of the REU program and on previous research evaluating the effectiveness of such programs [1-3, 15, 16]. Students demonstrated significant gains in a measure of broad research experience targeting program elements such as experience working in a research lab and experience working with faculty and students in research settings. Students also demonstrated significant gains in a measure of specific research-based skills which targeted skills related to lab work, communication of research findings, and conceptual knowledge of research and research-based processes. Further, students rated themselves as open to collaborating with other students and faculty during research both before and after completing the program. Ratings of program elements indicated positive ratings of the working relationship with research mentors, the working relationship with research group members, the amount of time spent with research mentors, and the advice given about graduate school. Improvement was suggested, based on low program ratings and information obtained during interviews, for the element of amount of time spent doing meaningful research. Several REU program participants also indicated anticipated completion of a presentation, talk or poster at a professional conference (25%) and involvement in co-writing a paper for either an academic journal or an undergraduate research journal (33%). Approximately 58% of participants indicated plans for some level of graduate school.

Interviews of program participants largely corroborated the indication of research-based gains and provided a more in-depth understanding of the impact of the program. Research mentors likewise corroborated student gains in research-based skills, including experience with lab procedures and analytical skills. Research mentors also suggested benefit in hosting undergraduate students during the course of the program; one feature of this benefit was the ability of graduate students to develop experience mentoring and teaching undergraduate students interested in research [17]. The primary suggestions for improvement centered on structural and organizational elements of the program.

Based on the current work and building on the work of prior evaluations of REU programs, several implications for the implementation of undergraduate research programs are supported by the current study [1, 18-19]. These implications expand on those presented in the initial evaluation of this program. First, undergraduate research programs benefit from clear structure and

organization, both of programmatic features, including scheduled research time and professional and research development workshops (e.g., communicating research finding, graduate school information seminars, structured student presentations of research findings, etc.) and of student-based objectives and requirements. This structure is likely to be beneficial particularly at the outset of the program given the variability observed in participating students' prior experiences and skill levels. Such structure is also helpful given the perceived fast-paced and intensive nature of structured undergraduate research programs. In other words, clear and early delineation of program goals and requirements, pairings with faculty and graduate student mentors, project aims and goals, and the research-based tasks in which students will likely engage is necessary to allow students to progress early on in the ten week program.

Next, students indicate benefit from the ability to collaborate with others, including other undergraduate research participants and graduate student mentors, while conducting research and completing research-based requirements. The incorporation of collaborative elements in undergraduate research programs has shown initial promise and may be beneficial in terms of students' perceptions of inclusion, integration, and perceived gains in research experiences. This could reflect the assignment of two undergraduate student participants to the same or similar research projects. Collaboration also seems to facilitate skills related to work completion and management as reported by students participating in the REU program across the first and second years. Embedding opportunities for students to share project goals and requirements – contingent on the articulation of clear and individualized expectations for project completion – appears to benefit students' experiences during REU programs. Related to this suggestion and based in part on prior evaluation of the current NSF-funded REU, the communication of clear and explicit research project expectations, particularly when students are working together on research projects, is likely to foster both collaboration and autonomy in effectively completing research-based and project-based requirements.

Acknowledgements

This material is based in part on an REU site supported by the National Science Foundation under grant number 1359365. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Bibliography

1. Follmer, D. J., Zappe, S. E., Kumar, M., & Gomez, E. 2015. Preliminary evaluation of a research experience for undergraduates (REU) program: A methodology for examining student outcomes. Proceedings, American Society for Engineering Education, Seattle, WA.

2. Bielefeldt, A. R. 2012. Student learning outcomes from an environmental engineering research program. *Proceedings, American Society for Engineering Education*, San Antonio, TX.

3. Hsieh, S-J. 2013. Research experiences for undergraduate engineering students. *Proceedings, American Society for Engineering Education*, Atlanta, GA.

4. Goldberg, M. R., Cooper, R. A., Ding, D., & Koontz, A. 2011. Using experiential learning to inspire, educate, and empower underrepresented undergraduates in STEM. *Proceedings, American Society for Engineering Education*, Vancouver, CA.

5. Willis, D., Krueger, P., & Kendrick, A. 2009. The influence of a research experiences for undergraduates program on students' attitudes toward engineering research. *Proceedings, American Society for Engineering Education*, Austin, TX.

6. Kardash, C. M. 2000. Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology, 92*, 191-201.

7. Zydney, A. L., Bennett, J. S., Shahid, A., & Bauer, K. W. 2002. Impact of undergraduate research experience in engineering. *Journal of Engineering Education, 91*(2), 151-157.

8. Seymour, E., Hunter, A-B., Laursen, S. L., & Deantoni, T. 2004. Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education, 88*, 493-534.

9. Lopatto, D. 2007. Undergraduate research experiences support science career decisions and active learning. *CBE Life Sciences Education, 6*, 297-306.

10. Yoder, B. L. 2013. Engineering by the Numbers. American Society for Engineering Education. 37 pp. http://www.asee.org/papers-and-publications/publications/14_11-47.pdf

11. URSSA, Undergraduate Research Student Self-Assessment. 2009. Ethnography & Evaluation Research, University of Colorado at Boulder, Boulder, CO. www.salgsite.org

12. Weston, T. J., & Laursen, S. L. (2015). The Undergraduate Research Student Self-Assessment (URSSA): Validation for use in program evaluation. *CBE-Life Sciences Education, 14*(3), 1-10.

13. NVivo qualitative data analysis software; QSR International Pty Ltd. Version 10, 2012.

14. D. R. Thomas, A general induction approach for qualitative data analysis. *American Journal of Evaluation. 27*(2): 237-246, 2006.

15. Pierrakos, O. & Trenor, J. 2009. Using a mixed-methods approach to investigate students' perceived learning and challenges faced during a summer undergraduate research experience. *Proceedings, American Society for Engineering Education*, Austin, TX.

16. Sutterer, K., Brenny, M., Pirnia, J. D., Woodward, M., Houghtalen, R., & Hanson, J. 2005. Engineering REU sites: Designing for appropriate and valuable summer educational experiences. *Proceedings, American Society for Engineering Education*, Portland, OR.

17. Guerrero, C. D., Labrador, M. A., & Pérez, R. A. 2007. Graduate students mentors in REU sites. *Proceedings, American Society for Engineering Education*, Honolulu, HI.

18. Pariyothorn, M. & Autenrieth, R. L. 2012. Strategic use of summer undergraduate research experiences. *Proceedings, American Society for Engineering Education*, San Antonio, TX.

19. Minerick, A. R. 2008. Advice for new faculty: Structuring a summer REU project and mentoring the participant to a publication. *Proceedings, American Society for Engineering Education*, Pittsburgh, PA.

20. Minerick, A. R. 2008. NSF REU Site: Chemistry/Chemical Engineering: The bonds between us – A three year retrospective. *Proceedings, American Society for Engineering Education*, Pittsburgh, PA.