# Defining a Successful Undergraduate Research Experience in Engineering

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## Abstract

In recent years, there has been interest in broadening the participation of students in undergraduate research experiences in engineering disciplines. While there has been considerable study and analysis of the benefits achieved by high-achieving undergraduate students engaged in research activities, relatively little consideration has been given to the impact and benefits of research experiences on engineering students who are better described as "average". Yet, these are the students to whom undergraduate research opportunities need to be provided in order to achieve broader participation. Therefore, it is beneficial to understand how these experiences impact average students so that programs are not designed that will not meet the students' expectations or needs.

The primary purpose of this NSF-sponsored work is to provide definitions of what constitutes a successful undergraduate research experience for a wide range of students. Particular attention is devoted to students whose academic background and performance is solid, but not outstanding. For such students, some of the benefits for high-achieving students, such as increased likelihood of graduate school attendance, may not be appropriate measures of a successful experience. Through surveys and interviews of students who have engaged in undergraduate research experiences in engineering, we have developed a preliminary definition of a successful research experience. Specifically, a successful research experience for these students should develop the skills necessary for these students to be practicing engineers, increase their confidence in what?, and be centered around an experience that allows students to learn how to conduct a research project.

In addition to the preliminary definition of a successful undergraduate research experience, this paper also presents insights gained from the study with respect to what makes the experience more positive for the students.


## Introduction

With the interest in recent years to increase the number of graduates from STEM disciplines [1,2], many ideas have been put forth and enacted upon to accomplish this task. One of these ideas is to increase the number of STEM students engaged in undergraduate research experiences. Improving student retention in a discipline and inspiring more students to pursue graduate studies are two of the reasons that are commonly given for encouraging participation in undergraduate research. [3-7]. While the former reason is supportive of the desire to graduate more students in engineering, the latter reason is less connected to the concept. However, the desire to use undergraduate research experiences to attract more students to graduate school tends to focus recruitment on higher-achieving, more academically-successful students. These students are more likely to finish their degrees than weaker students. Therefore, using undergraduate research projects may not be a productive way to increase the number of engineering graduates, if the students who are engaging in the projects are already strong academically. In order to gain a better understanding of the effectiveness and usefulness of engaging in undergraduate research for a broader range of students, there is a need to study students who are not among the elite students in the nation, but who still participate in undergraduate research.

The University of Wisconsin-Milwaukee (UWM) is an urban, doctoral, research institution. Students in the College of Engineering and Applied Science (CEAS) at UWM range from being relatively strong to being rather weak, in comparison to engineering students nationwide. For example, the mean ACT score of freshmen entering CEAS in the Fall 2013 semester was 25.8, which is the highest it had been in at least 10 years. Such an average indicates that there are many students in CEAS who could attend most engineering schools in the nation, but there are also a large number who may have difficulty being accepted into other schools. Yet, as a research institution, most faculty have active research programs and employ undergraduates as part of their research programs. Typically, about 70 undergraduate students each year in CEAS participate in research projects.

The large majority of students in CEAS do not intend to directly enter graduate school upon graduation, and are more focused on obtaining a job in industry upon completion of their program. In addition, most of the students work part-time while in school, and relatively few graduate in 4 years (most require 5 or 6 years to graduate). This type of student has been the focus of few studies with respect to the impact of undergraduate research experiences. As a result, little is known about what the expectations are for such students or what should be considered a successful research experience for such students. The profile of students at CEAS, coupled with the availability of research projects, offers a promising inroad into better understanding the potential impact of undergraduate research on a wide-range of students, including students who are more vulnerable to leaving STEM disciplines.

In this paper, the results of a study analyzing what “average” undergraduate engineering and computer science students are seeking and achieving from research experiences are presented. Preliminary results of what benefits were achieved by students during their research experience are presented, as well as what might have improved their experiences. Taken as a whole, these results provide a strong foundation from which to develop a final definition of what constitutes a successful undergraduate research experience, from students’ perspectives, for non-elite engineering and computer science students.

## Background

Improving student retention in a discipline and inspiring more students to pursue graduate studies are two reasons that are commonly given for encouraging participation in undergraduate research [3-7]. The logic behind these assertions is reasonable: students who become involved in state-of-the-art research in their discipline can become more engaged in, and develop a deeper understanding of, their field. In some cases, this engagement helps to increase the retention of students if they begin research early in their undergraduate careers. This engagement can also give students more confidence in their abilities and increases their interest in attending graduate school. However, some undergraduate students are actually dissuaded from continuing their studies as they learn more about their discipline and experience some of the frustrations typical of research endeavors [8].

In addition to improving retention rates and increasing the number of students pursuing graduate studies, the benefits of developing skills associated with undergraduate research experiences (UREs) in engineering and science are reported to include a better understanding of the research process, improved communication and collaboration skills, the development of problem-solving skills, and enhanced critical thinking skills [9-10]. These are attributes that are often seen as necessary outcomes of an engineering program, and many are specifically included in the ABET accreditation criteria [11]; therefore, even if a URE does not lead a student to pursue graduate studies, there are potential professional development benefits.

A substantial amount of research has been devoted to students who participate in special summer Research Experiences for Undergraduates (REU) programs. For example, Willis, *et al*. studied the impact of an NSF-sponsored REU on ten students in mechanical engineering and found that, while the students gained experience and knowledge, the number of students who were strongly considering graduate studies declined while participating in program [8]. Hung, *et al*. considered students at a summer REU focused on micromachining, which had a large percentage of students from groups underrepresented in engineering; their findings demonstrated that most of the students wished to pursue a research career through graduate school [12]. Mahmud and Xu found that students' participation in an REU resulted in an improvement in their technical communication skills [13]. Finally, Willits and Barnett performed an initial evaluation of the impact of an REU program in bioengineering for students transitioning between their first and second years in college [14]. As this program was targeted towards students early in their collegiate programs, the researchers planned to track the students as they continued their studies. Such data can enhance our understanding of the impact of a URE on retention.

In addition to these studies, Hathaway *et al*. considered 291 students involved in undergraduate research at the University of Michigan from a wide range of disciplines. They found that structured programs led to more positive results than unstructured UREs, in terms of pursuing graduate studies and that students with a wide range of abilities can benefit from a URE. They also found that first-year students can benefit significantly from a URE [15]. Nagda *et al.* studied the same program at a different time period, considering over 600 students, and found that retention of African-American students increased considerably by participation in research, and that participation during the sophomore year was generally more beneficial than during the freshman year [16]. Seymour *et al*. and Hunter *et al*. considered the impact of summer research on students in sciences at a primarily liberal arts school. They found that many students developed personal and professional skills through the URE and that the research. However, the experience did not appear to inspire seniors to pursue graduate studies and, in some cases, students were actually less likely to pursue graduate school after learning about the inherent difficulties associated with research while they were still undergraduates [17,18]. Kang conducted a study of UREs of predominantly underrepresented minorities involved in science research and found that UREs may help this population advance through graduate studies [19].

Russell *et al*. conducted an extensive survey of thousands of undergraduates who had participated in undergraduate research in STEM disciplines, as well as faculty and graduate student mentors of these students. Many of the respondents had participated in NSF-sponsored programs and the undergraduates tended to have high grade point averages. This study found that having an undergraduate research experience increased students' confidence and raised students' awareness of graduate school. Moreover, the number of students who expected to obtain a Ph.D. noticeably increased after participating in an URE [20].

These studies illuminate a number of problems that develop when one wishes to study the broad impact of research experiences on average students. First, many of the studies focus on high-achieving students selected to participate in competitive summer REU programs. Second, focusing on summer programs neglects students that participate in URE during the normal academic year, when it may be difficult to balance this experience with coursework. Third, many of the studies only considered a very small number of students, which limits the generalizability of the results. Fourth, many of the studies in STEM disciplines have concentrated on students in the hard sciences, who may not have as many career options as engineering and computer science students completing a B.S. degree. Students in the hard sciences may be inherently more focused on developing skills necessary for graduate school, whereas engineering students may be inherently more interested in finding a job in industry. This study was developed to fill these identified gaps in the knowledge base, particularly what constitutes a successful URE for average students in engineering or computer science.

## Description of Study

The preliminary results reported in this paper were obtained through a two-part study of engineering and computer science students who had completed undergraduate research projects in CEAS in the last two years. The first part of the project involved an on-line survey of students. The results of this survey were then used to identify students for the second part of the project, which involved in-person interviews with these selected students to gain a deeper understanding of their experiences as engineering students participating in undergraduate research.

The on-line survey was sent to 110 students who had recently participated in undergraduate research in CEAS. Forty-one students responded to the survey and completed it, representing a 37.3% response rate. The survey collected demographic information on the students, including age, gender, race and ethnicity, major, GPA, parents' educational background, and year in school. Students were also asked to identify the faculty member they worked with, the duration of their URE, and to rate their perceived quality of the relationship they had with their mentor on this project. If students worked for more than one mentor, they were asked to respond to these questions separately for each experience. For each experience, students were asked how much time they spent on the project each week and with whom they primarily interacted (faculty, graduate students, or undergraduate students). They were also asked to identify the nature of their work (experimental, theoretical, computational, clerical, or other). Then, considering their experiences as a whole, they were asked to identify their perceived benefits from participating in undergraduate research. The options provided as perceived benefits are listed in Table 1. Finally, students were asked if they would recommend undergraduate research to others, and to categorize their post-graduation plans.

In the survey, students were provided with an opportunity to volunteer to be interviewed in detail about their experiences. Approximately half of the student respondents indicated a willingness to be interviewed, and from those that volunteered 12 students were selected to be interviewed. Students were selected for interviews in an attempt to gain a broad perspective of experiences from a diverse group of students, including students with diversity in gender, GPA, and major perspectives. Unfortunately, there were not enough survey respondents from underrepresented minority groups to provide significant diversity based on race and ethnicity. While the interviewer did adapt to the responses of the students, the primary questions posed during the interviews are listed in Table 2. The interview responses were grouped into several themes: motivation, demographic information, student’s daily work experience, student’s perception of support from supervisor, student’s professional development, and student’s perception of the value of URE. From these, the perceived benefits of UREs, as well as the factors that may influence the success of a particular URE, were developed.

**Table 1**: Listed potential benefits presented to students in the on-line survey.

| Number | Perceived Benefit |
|---|---|
| 1 | Developed my critical thinking skills |
| 2 | Developed my communication skills |
| 3 | Developed my problem solving skills |
| 4 | Learned how to work independently |
| 5 | Learned how to work as part of a team |
| 6 | Learned how to conduct a research project |
| 7 | Improved my relationship with faculty and/or other students |
| 8 | Increased confidence in my research skills |
| 9 | Increased confidence in becoming a successful engineer/professional |
| 10 | Academic coursework became more relevant |
| 11 | Developed/increased interest in pursuing graduate studies |
| 12 | Other |

**Table 2**: Primary in-person interview questions posed to the students during the interview.

| Number | Question |
|---|---|
| Q1 | Why did you choose engineering as a major? |
| Q2 | How did you learn about undergraduate research experiences (URE)? |
| Q3 | What did you hope to get out of your URE? |
| Q4 | What was a typical day like? |
| Q5 | Tell me about the projects you worked on and the tasks assigned to you. |
| Q6 | What stands out about this experience when you think about it? |
| Q7 | Who did you mostly interact with during the project? Who was guiding you? How was your relationship with him/her/them? |
| Q8 | What were the best parts of the experience? The worst parts? |
| Q9 | What do you feel you learned in your URE? (Research topic, major, research in general) |
| Q10 | What have you learned about yourself? |
| Q11 | What other benefits do you feel you got from the experience? |
| Q12 | What skills do you think you developed in the experience? |
| Q13 | Has the experience made you think differently about your decision to become an engineer? |
| Q14 | How has the URE influenced your career goals? |
| Q15 | Based on your experience, would you recommend a URE in engineering to all or some of your fellow students? Why? |
| Q16 | What would have made your URE better? What can be done to improve UREs for other students? |

**Results and Discussion**

Figure 1 depicts students' perceptions of the benefits received from their undergraduate research experience. The number listed for each benefit refers to the numbering system used in Table 1. In addition to the forced choice responses shown, three students wrote in a perceived benefit. However, those three listed benefits were captured by the forced choice responses, with the possible exception of "Learned to ask questions". As a result, only the 11 benefits listed in Table 1 will be focused on, as well as the impact that the URE had on these students with respect to these benefits.

All of the listed benefits were identified by at least 60% of the students, and, as such, all should be considered as reasonable expectations of a URE for students in general. However, the benefits that were identified by a larger percentage of students are more relevant, in terms of their inclusion in a definition of a successful URE, since they are likely to be experiences by more students. Specifically, four benefits were identified by at least 80% of the students. These include (3) Developed my problem solving skills, (4) Learned how to work independently, (6) Learned how to conduct a research project, and, (7) Improved my relationship with faculty and/or other students. These four benefits are the most reasonably expected benefits that students will gain from their undergraduate

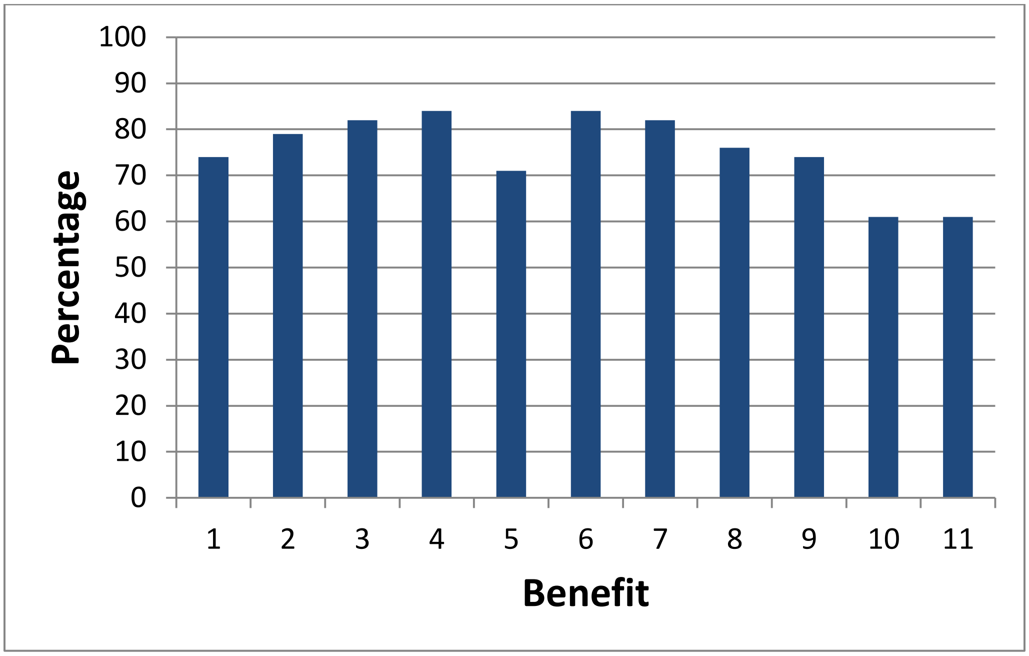


**Figure 1**: Percentage of students (n=41) who responded in the survey that they received the particular benefit (as numbered in Table 1) from their URE.

research experience. At the other end of the scale, (10) Academic coursework became more relevant; and (11) Developed/increased interest in pursuing graduate studies were listed by only 61% of the respondents. This was 10 percentage points lower than any other benefit, and therefore may not be as appropriate for consideration of what should be expected of students as a whole, regarding a successful undergraduate research experience.

With these two benefits being less cited by students, there may be a need to rethink the purpose of UREs, with respect to average students. First, consider the impact of the URE on graduate school interest. While a relatively lower percentage of students indicated this was a perceived benefit, most of the students in CEAS are not planning on graduate studies immediately following graduation. Therefore, if the undergraduate research experience increased graduate school interest in 61% of the students in the sample this may be a rather significant impact. On the other hand, since this benefit is perceived by only approximately 3 out of every 5 students, it is likely not a factor that should be considered the driving motivation for extending URE opportunities to average students.

The other low-scoring perceived benefit, "Academic coursework became more relevant", is also of interest. One reason why some promote the expansion of undergraduate research is to increase retention, presumably by making the coursework more interesting and showing reasons for studying the material. Yet only 61% of the respondents indicated that their URE made their coursework more relevant, which implies that 39% did not agree with this assertion. There are several possible explanations for this relatively low score. First, 39% of respondents may have recognized the relevance of their coursework prior to participating in an URE, which would imply that the research experience did not make the coursework “more relevant”. Second, the research project may have focused on a subject that was well beyond their coursework, making it difficult to connect more fundamental topics covered coursework to the research project. This is certainly a possibility, particularly if they were assisting a doctoral student on their research. Third, respondents may have been working on a project that was in a different discipline from their own area of study. If so, the URE is not likely to assist with retention in their field of study and may actually drive students into a different discipline. Fourth, the material being covered in coursework may not be applicable to the research projects respondents were working on. This explanation begs the question of whether the material being covered in today’s engineering courses and curricula is relevant to cutting-edge research and whether students are being well-prepared for their future careers by their current programs.

It is also interesting to compare the results of respondents that reported a perceived benefit of working independently to those that reported a perceived benefit of learning how to work as part of a team. In the survey, 84% indicated that the URE helped them learn how to work independently, while 71% indicated that the URE helped them learn how to work in a team. Learning teamwork skills has also been promoted as a benefit of undergraduate research, and being supported by 71% of the respondents does support this assertion. But, if this is a primary goal of the URE, then these results do suggest a potential shortcoming with the way in which some research experiences are designed. Since 13% more of the respondents identified learning how to work independently work as a perceived benefit, when compared to learning how to work as part of a team, it would seem that more research projects are designed such that students work independently. If one of the primary goals of an URE is to promote teamwork skills, research experiences may need to be redesigned to promote working in teams.

Greater insight into the thoughts of the students was obtained through the in-person interviews with the students. Some of the more relevant results are listed below.

1) Most of the students interviewed did not come into college with the plan of conducting undergraduate research. The students who did eventually pursue a URE did so primarily to gain experience in the engineering field, with half of those interviewed specifically mentioning it as an alternative to an internship or co-op. Eight of the 12 interviewed saw it as a path to graduate school, which was the same number of interviewees that perceived this work to be of personal interest to them. Only 4 identified finances as a motivation to do an URE. (As a side note, UWM has an office of undergraduate research, and CEAS has had an expo to promote undergraduate research; neither of these had much impact in drawing the interviewed students into their URE.)

2) The benefits that the interviewed students hoped to gain from the URE were to gain experience and to develop applied engineering skills. Some did perceive the URE as a path to graduate school.

3) The primary activities performed by interviewees during their URE were data collection, data analysis, computer-related tasks (including simulations), and performing literature reviews. These are tasks that one would expect from a research experience. Five of the 12 also indicated that they performed administrative work, which would not necessarily be thought of as research.

4) Interviewees reported a wide-range of variability, in terms of the level of instruction and guidance they received from their mentors. Some students were very pleased with the interaction with their mentor, who may have been a graduate student working with the faculty advisor; while others thought that there was a lack of guidance. Generally, the students preferred more guidance and instruction, as long as it was not stifling.

5) Students primarily worked with graduate students, and those that worked with graduate students reported mostly positive experiences with these interactions. Most interviewees felt that they received adequate guidance from their faculty advisor; however, those who felt that they did not receive adequate guidance from their faculty advisor were more likely to have had a negative overall experience.

6) Students who were able to attend conferences and work on preparing publications cited this as a great benefit.

7) Most of the students interviewed felt that the URE led to personal and professional development. In addition, approximately half of the students reported that the URE gave them greater clarity, in terms of their career goals. Most students felt the URE helped them to develop applied engineering skills. Those students who were able to attend conferences or work on developing manuscripts felt that their experience helped to improve their communication skills.

8) All of the students interviewed indicated that the URE was a worthwhile experience, and the majority of the students would recommend that their peers participate in an URE.

From these results, it can be inferred that having an URE will usually help participants to develop their applied engineering skills. There is also an opportunity to greatly impact communication skills through an URE, particularly if the URE encouraged and promotes students to participate in conferences and the development of manuscripts. For students interested in graduate school, the URE does offer participants a chance to experience the research process, as well as a chance to gauge their interest in doing research before committing to graduate school. However, for average students not already interested in graduate school, the URE does not appear to be a strong motivator for graduate school.

The interviews also provided some insights as to how the URE can be improved for students. First, students need to be working on real engineering research work, as opposed to primarily clerical or administrative tasks. Second, students should be provided with adequate guidance and instruction, by either a faculty member or a graduate student. Third, designing the experience so that the student becomes part of the research community (attending conferences, writing papers) will likely provide the student with more benefits.

When taken as a whole, the results of the survey and the in-person interviews can lead to a preliminary definition of what a successful undergraduate research experience is for the average students considered in this project.  The goals for a successful URE for these students are

1)  The URE should develop applied engineering, critical thinking, and problem solving skills of the students to help prepare them for a career as an engineer, likely in industry.

2)  The URE should improve the communication skills of the student.

3)  The URE should increase the confidence of the student in their abilities, and help clarify their career goals.

4)  The URE should both help the student learn to work independently and as part of a team.

5)  The URE should provide the students with an understanding of how to conduct a research project.

Note, with more input from additional students as well as input from other constituents this definition may be modified.  At this time, this represents the perspective of the students involved with the UREs.  It should also be noted that this definition does not preclude other benefits from being gained by the students.  For example, a URE may inspire a student to go to graduate school and become an accomplished researcher. However,  this is not necessary for an URE to be successful. Similarly,, a URE may with retention and graduation for some students, but again, this is not something that appears to be a defining goal of a URE for these students.

It can also be noted that the influence of demographics on the perceived benefits by students was explored.  However, the sample sizes in each demographic group were too small to see any particular benefit being cited by a particular group in any meaningful way.

The average number of benefits cited in the survey was 7.6 and there was no statistically significant difference between the number of benefits cited by men vs. women, by students whose mother received a college degree or not, or by GPA category (2.0-2.99, 3.0-3.49, 3.50-4.0).  While not statistically significant, it can be noted that students in the highest GPA category and students who planned to go to graduate school did see more benefits on average.  Students who planned to go to graduate school saw an average of 9.4 benefits, while students who planned to work in the private sector saw an average of 7.6 benefits (and 11 students had other post-graduation plans, or were unsure).  Students in the 3.50-4.0 GPA category saw 8.1 benefits, versus 7.2 benefits in the middle category, and 7.5 benefits in the 2.0-2.99 category.

## Summary

In this paper, the results of a survey of undergraduate engineering and computer science students who participated in undergraduate research experiences at UWM in CEAS were presented. In addition, a summary of interviews that were conducted on a subset of these students was also presented. While some of these students are very good, overall these students generally would not be considered among the elite engineering students in the United States, and therefore represent a portrait of engineering undergraduates more typical of the nation as a whole than previous studies of undergraduate research.

From this work, a preliminary definition of what would be considered a successful URE, by students who participate in UREs, was developed and presented. These UREs should develop applied engineering, critical thinking and problem solving skills, develop communication skills, increase student confidence, help students learn to work both independently and as part of a team, and should similar enough to a real research experience so that the students can learn how to conduct their own research projects. While other benefits may be experienced by particular students, they should not be considered an expectation for a successful URE for most engineering students.

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## Bibliography

1. National Science Board. 2003. The Science and Engineering Workforce: Realizing America's Potential. Publication NSB 03-69. (www.nsf.gov/nsb/documents/2003/nsb0369/nsb0369.pdf)

2. Augustine, N. "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future", Committee on Science, Engineering, and Public Policy (COSEPUP), 2007.

3. A.L. Zydney, J.S. Bennett, A. Shahid, and K.W. Bauer, "Impact of Undergraduate Research Experience in Engineering," *J. Engineering Education*, **91**: 151-157. (2002)

4. R.L. Morley, J.J. Havick, and G.S. May, "An evaluation of the Georgia Tech Summer Undergraduate Program of Research in Electrical Engineering for Minorities. *J. Engineering Education*, **87**: 321-325. (1998)

5. K.B. Schowen, "Research as a Critical Component of the Undergraduate Educational Experience." *Assessing the Value of Research in the Chemical Sciences*. National Research Council Report, National Academy Press: 73-81. (1998)

6. E. Seymour, A.-B. Hunter, S. Laursen, and T. DeAntoni,. "Establishing the Benefits of Research Experiences for Undergraduates: First Findings from a Three-Year Study." *Sci. Educ*., **88**, 493-594. (2004)

7. D.W. Mogk, "Undergraduate Research Experiences as Preparation for Graduate Study in Geology," *J. Geological Education*, **41**:126-128. (1993)

8. D. Willis, P. Krueger, and A. Kendrick, "Perceptions, Expectations, and Outcomes of the Third Year of a Research-Experiences for Undergraduates Program," *2010 ASEE Annual Conference* Paper No. AC 2010-1721. Louisville, KY. (2010)

9. A.L. Zydney, J.S. Bennett, A. Shahid, and K.W. Bauer, "Faculty Perspectives Regarding the Undergraduate Research Experience in Science and Engineering," *J. Engineering Education,* **91**: 291-297. (2002)

10. C.M. Kardash, "Evaluation of an Undergraduate Research Experience: Perceptions of Undergraduate Interns and Their Faculty Mentors," *J. Educational Psychology,* **92**: 191-201. (2000)

11. ABET, Inc., "Criteria for Accrediting Engineering Programs," http://abet.org/uploadedFiles/Accreditation/Accreditation_Step_by_Step/Accreditation_Documents/Current/2014_-_2015/E001%2014-15%20EAC%20Criteria%203-13-14%282%29.pdf . (2014)

12. W. Hung, J. Leon, and L. San Andres, "Research Experiences for Undergraduates in Micromanufacturing," *2010 ASEE Annual Conference,* Paper No. AC 2010-2373. Louisville, KY. (2010)

13. S.M. Mahmud and C.-Z. Xu, "REU Program in Telematics and Cyber Physical Systems: Sharing Strategies, Experience, and Lessons Learned to Help Others," *2010 ASEE Annual Conference,* Paper No. AC 2010-2361. Louisville, KY. (2010)

14. R. Willits and D. Barnett, "Early Career Bioengineering Research Experience for Undergraduates," *2010 ASEE Annual Conference,* Paper No. AC 2010-1038. Louisville, KY. (2010)

15. R.S. Hathaway, B.A. Nagda, and S.R Gregerman, "The Relationship of Undergraduate Research Participation to Graduate and Professional Education Pursuit: An Empirical Study," *J. College Student Development.,* **43**: 614-631. (2002)

16. B.A. Nagda, S.R. Gregerman, J. Jonides, W. von Hippel, and J.S. Lerner, "Undergraduate Student-Faculty Research Partnerships Affect Student Retention," *The Review of Higher Education,* 22: 55-72. (1998)

17. E. Seymour, A.-B. Hunter, S.L Laursen, and T. DeAntoni, "Establishing the Benefits of Research Experiences for Undergraduates in the Sciences: First Findings from a Three-Year Study," *Science Education*, **88**: 493-534. (2004)

18. A.-B. Hunter, S.L. Laursen, and E. Seymour, "Becoming a Scientist: The Role of Undergraduate Research in Students' Cognitive, Personal, and Professional Development," *Science Education*, **91**: 36-74. (2007)

19. A. Kang, "UW Genom Project: A Successful Undergraduate Research Program," *2011 ASEE Annual Conference,* Paper No. AC 2011-2414, Vancouver, BC (2011).

20. S.H. Russell, M.P. Hancock, and J. McCullough, "Benefits of Undergraduate Research Experiences," *Science,* **316**: 548-549. (2007).