AC 2012-3192: GUIDING THEM TO GRADUATE SCHOOL: PROFESSIONAL DEVELOPMENT FOR UNDERGRADUATES PARTICIPATING IN ENGINEERING RESEARCH PROGRAMS

Dr. Katy Luchini-Colbry, Michigan State University

Katy Luchini-Colbry is the Director for Graduate Recruiting at the College of Engineering at Michigan State University, where she completed degrees in political theory and computer science. A recipient of a NSF Graduate Research Fellowship, she received her Ph.D. and M.S.E. in computer science and engineering from the University of Michigan. She has published more than a dozen papers related to her interests in educational technology and enhancing undergraduate education through hands-on learning. As a volunteer for Tau Beta Pi, the Engineering Honor Society, Luchini-Colbry facilitates interactive seminars on interpersonal communications and problem solving skills for engineering students across the U.S.

Dr. Korine Steinke Wawrzynski, Michigann State University

Director, Undergraduate Research

Rachel Mangiavellano, Michigan State University
Evan McCune, Michigan State University

Guiding them to Graduate School: Professional Development for Undergraduates Participating in Engineering Research Programs

Introduction

Participating in research as an undergraduate can be a strong predictor of students' success in Engineering graduate studies.[1–3] As an undergraduate research assistant, students are exposed to the practice and culture of academic research and have opportunities to observe the life and work of graduate students and faculty members first-hand. Graduate school recruiters actively seek undergraduates with research experience, and solicit prospective graduate students through "information booths" at conferences where students present results of their undergraduate research experiences.

This paper discusses a series of professional development activities designed to help prepare undergraduate researchers for graduate studies in Engineering. Specifically, students participated in (1) bi-weekly seminars covering topics in interdisciplinary Engineering research; (2) bi-weekly workshops on the graduate school application process; (3) writing assignments to help students clarify their interests and begin developing application materials for graduate school; (4) individual and small-group outreach activities to encourage broader participation in STEM (science, technology, engineering and math); (5) interdisciplinary networking events with undergraduates, graduate students, and faculty from across campus; and (6) presentation of their research at a university wide research forum. These professional development activities were implemented as part of a 10-week summer research program for undergraduates sponsored by the College of Engineering at Michigan State University (MSU). In 2011, fifty undergraduates from 18 majors and 5 institutions participated in the summer research program, working with 47 faculty mentors from 8 Engineering disciplines.

We assessed our professional development activities through pre- and post-experience surveys, asking students about their background, expectations, and experiences. The pre- and post-testing indicate that the professional development activities were very successful in helping students understand and prepare for the graduate school application process. Participating in the summer research program also had an impact on students' future plans: 96% of students indicated on the post-survey that they planned to attend graduate or professional school, versus 73% on the pre-survey. On the final survey, 98% of students indicated that they planned to pursue another faculty-mentored research experience, and students reported modest gains in their ability to write a research abstract and to create a research poster.

Background

Undergraduate research is an experiential, inquiry-based learning experience that combines elements of research and teaching in an interactive process that engages students with faculty and their scholarship.[4] Often referred to as a high-impact learning experience,[5] undergraduate research represents a powerful learning pedagogy because it provides students a hands-on, intense introduction to a specific academic discipline for an extended period of time under the guidance of a faculty member.[6] Developing relationships with faculty and graduate students can

also help undergraduates learn more about graduate school and graduate-level research.[3,7] Indeed, the National Science Foundation calls undergraduate research "one of the most effective avenues for attracting talented undergraduates to, and retaining them in careers in, science and engineering, including careers in teaching and education research."[8]

By engaging in an undergraduate research experience, students can make gains in academic, cognitive, and personal development. Through their research opportunity and interactions with faculty, graduate students, and peers, students advance their knowledge and understanding of a subject area, develop their skills in design and hypothesis construction, and improve their ability to collect and analyze data.[9–12] Working on their projects also helps students to improve organizational and time management skills, enhance written and oral communication abilities, learn how to work productively on a team, and develop their ability to tolerate and navigate obstacles.[9–12] Finally, students who participate in an undergraduate research experience often gain greater clarification or confirmation regarding graduate school or career plans,[1,2,9,13–15] as they learn about career possibilities and expectations of a particular discipline. While all students can benefit from such a learning experience, underrepresented student populations exhibit greater learning outcomes and increased student retention rates.[5,16–19]

Program Structure

The MSU College of Engineering Undergraduate Research Experience is a 10 week summer program (mid-May through July) offering full-time, paid research internships for high-achieving undergraduates. Students are expected to devote full-time effort to research and must agree not to enroll in summer classes (exceptions may be made for 4 credits or less of online coursework). Individual faculty-student pairs may agree to extend the research experience beyond the 10 week program, and occasional accommodations are made for students with academic or personal commitments that conflict with the program calendar.

An orientation and welcome is held on the first day, and the final day includes a closing presentation and picnic for students and faculty. In addition, students participate in 10 weekly professional development seminars and present research posters at a campus-wide forum in the last week of the summer program. Students' individual research experiences vary widely depending on their interests and placement within the program. In Summer 2011, some students did extensive fieldwork to test contamination levels in local water sources and developed improved filtration methods, while other students worked in an office setting developing computer simulations or analyzing data. MSU has several Engineering research facilities located across campus and in surrounding communities, and many students work at these sites. The required weekly seminars were are in the main Engineering building on campus, and are scheduled mid-morning to encourage students to socialize before and after the seminars.

Students are paid $11/hour, up to $4,400 for the 10-week program, and are responsible for taxes and living expenses. A variety of housing options are available both on- and off-campus, and the program coordinator works with students from other institutions to secure local housing. 40% of the funding comes from the University (through the Office of the Provost and the College of Engineering) and the remainder comes from the faculty and/or department.

Application and Matching Process

Applications are accepted online through the end of February, and the matching process takes place in March. Undergraduates from any institution and any major are eligible to apply, provided they have a cumulative grade point average of 3.2 or higher (on a 4.0 scale) and that they will return to college for at least one full semester after completing the summer research program. For the 2011 summer research program, applications were received from 169 students from 19 institutions, with an average GPA of 3.63/4.0. Students submitted transcripts and a brief statement of their research interests, and indicated their preferences for a research group or faculty mentor (selected from the research and faculty information provided on departmental websites). Table 1 summarizes the distribution of applications by class level (as of Fall 2011) and gender across the six Engineering departments.

Table 1: Class Level and Gender Distributions for 2011 Program Applicants

Engineering Department	Senior	Junior	Sophomore	Men	Women
Biosystems	9	5	2	10	4
Civil & Environmental	9	9	2	16	3
Chemical & Materials Science	24	16	9	31	15
Computer Science	7	10	1	14	3
Electrical	9	10	1	13	5
Mechanical	22	18	6	30	15
Total (169 Applicants)	80 (46%)	68 (41%)	21 (13%)	114 (68%)*	45 (26%)*

**Gender information was not available for 10 of the 169 applicants.*

In addition to the 169 applications that were reviewed, 46 other applications were received from students who did not meet the program criteria, who did not submit a complete application, or who withdrew their application before the matching process began (typically, students withdrew to accept another internship). Since we had 169 valid applications but only funding for 50 students, we allocated the internship spots to departments in proportion to the number of applications to that department. For example, Mechanical Engineering had the most applicants (46) and received funding for 14 summer internships, while Biosystems Engineering had 16 applicants and was allocated 5 internship spots. With this proportional distribution, each applicant had about a 30% chance of being selected.

The matching process was coordinated by the graduate program director in each department, with help from faculty and support staff. Application materials were forwarded to faculty who were interested in mentoring student researchers, and faculty selected students on a first-come, first-served basis. Students received individual offer letters, specifying their faculty mentor and department, on a rolling basis beginning in late March. Students were asked to make a decision by April 15, and accepted by signing a letter of commitment indicating that they understood the program requirements and agreed to participate. Requiring students to sign a commitment letter has virtually eliminated previous problems with students who initially accepted a research internship and then reneged late in the semester to take another position, usually in industry.

Professional Development

In addition to their individual research with faculty, students participated in a series of professional development activities designed to introduce them to life as a graduate student. Specifically, students participated in:

- **Research Seminars** covering topics in interdisciplinary Engineering research
- **Workshops** on the graduate school application process
- **Writing Assignments** to help students clarify their interests and begin developing application materials for graduate school
- **Research Forum** where students presented posters about their work over the summer
- **Outreach Activities**, completed individually or in small groups, to encourage broader participation in STEM (science, technology, engineering and math)
- **Networking Events** with other undergraduate researchers, graduate students, and faculty from across campus

The goal of these professional development activities was to engage participants in the greater University community and give them the opportunity to experience common elements of life as a graduate student.

Research Seminars

The five research seminars covered a wide range of topics in Engineering research. Students were introduced to the responsible conduct of research (RCR) and encouraged to complete additional training in RCR topics applicable to their own projects. The University provided access to a series of online training modules covering various topics, such as working with human or animal subjects, and students were expected to discuss RCR with their faculty mentor. Seminars in computational research and interdisciplinary research emphasized the breadth of Engineering exploration and the various computational tools and approaches for scientific research. In another seminar, students learned about engineering research careers in both academia and industry. Students also attended a seminar about developing effective poster presentations and ways to share their research findings with various audiences.

Workshops

The workshops were held approximately bi-weekly, alternating with the Research Seminars. The purpose of the Workshops was to help students prepare for graduate school, and included general topics ("Why Choose Graduate School?" and "The Graduate School Application Process") as well as specific tasks like developing academic resumes and graduate school application statements. The Workshops also helped to prepare students for the four required writing assignments: an academic resume, an academic statement, a personal statement, and a research statement.

Writing Assignments

The first three writing assignments – the academic resume, academic statement and personal statement – align with the types of information students are typically asked to provide on graduate school applications. The academic resume highlighted students' research and professional experiences. In the academic statement, students were asked to describe key experiences that led to their decision to apply to graduate school (e.g., research, internships, coursework) and their goals for graduate study and their career. In the personal statement, students were asked to describe how their background and life experiences – including social, economic, cultural, familial, educational or other opportunities or challenges – motivated their decision to pursue a graduate degree. Although graduate application requirements differ among institutions, these first three writing assignments cover the most common types of statements.

The final writing assignment was a research statement similar to one of the application requirements for the National Science Foundation (NSF) Graduate Research Fellowship.[20] Students were asked to describe their previous research experiences, focusing specifically on the problem or topic, their role in the research process, skills they developed, equipment or methods they employed, and the findings or implications of the research. Although few graduate school applications require such detailed research statements, this assignment was designed to help students reflect on their previous experiences and to clarify what they might pursue as a graduate student researcher. In addition, drafting one of the three required statements for the NSF application may encourage students to apply for that graduate fellowship program.

Research Forum

The University's Summer Undergraduate Research Forum (SURF) brings together undergraduate researchers from across campus in one central location where they have the opportunity to present their summer research projects to faculty, peers, and external audiences. Students register for the event on-line by submitting a project abstract, selecting an appropriate program category, and indicating their method of presentation (i.e., oral or poster presentation). They can participate as an individual or as part of a group. SURF provides students an opportunity to gain experience in discussing their research, to answer questions from faculty evaluators and guests, and to receive constructive feedback about their project and presentation.

A total of 126 students participated in SURF in Summer 2011, including 49 visiting summer students from 23 different institutions. Approximately 115 faculty members mentored these students on their projects. Students presented a total of 48 oral presentations in 4 categories (Agriculture and Animal Science; Biological Sciences; Natural Science and Engineering; Social Sciences) and 74 posters in 10 categories (Agriculture, Animal Sciences, and Environmental Resources; Biological Sciences; Biosystems and Agriculture Engineering; Chemical Engineering and Materials Sciences; Civil and Environmental Engineering; Computer Science and Engineering; Electrical and Computer Engineering; Mechanical Engineering; Natural Science and Engineering; and Social Sciences). Students were assigned a specific time to present their oral presentation or given a time block (i.e., 9:30 AM – 11:00 AM) to display their poster and be present to answer questions. Faculty and graduate students served as judges who evaluated the presentation or poster via a rubric. Students received oral feedback from their evaluator at the

event, which was followed by written feedback after the event concluded. Each participant received a copy of the program book that provided a compendium of all the abstracts.

Outreach Activities

As part of the summer research program, students were expected to complete a minimum of four hours of outreach activities. The goal was twofold: first, to help students understand the role of graduate students and faculty in reaching out to the larger community; and second, to engage the community in the research and learning activities of the institution. Students were allowed to select their own outreach activities and were encouraged to choose something that interested them and/or that allowed them to contribute their unique talents and interests. These outreach activities focused primarily on STEM (science, technology, engineering and math) activities. Examples include serving as a student panelist during visits by prospective Engineering undergraduates; volunteering at "Grandparents University" to assist community members in working with Lego robotics; and contributing to a Habitat for Humanity building project.

Networking Events

The Networking activities were designed to engage students in the broader University community and give students an opportunity to interact with students, faculty and researchers in a less formal setting. The first event was an ice cream social for undergraduate researchers from across MSU. In addition to the 50 participants in the Engineering summer program, 50 students from the MSU SROP (Summer Research Opportunities Program) and 40 students working independently with faculty during the summer attended the event. The two other networking events included dinners with graduate students and faculty members, where students learned about graduate student experiences and life as a faculty member. For these dinners, the undergraduates were divided by disciplines (Engineering and Natural Sciences, Life Sciences, Social Sciences) and had the opportunity to ask questions and interact with graduate students and faculty from similar backgrounds. The final networking event was a picnic that closed the summer research program; more than 100 students, faculty and staff attended.

Assessment Instruments

On their first day of the program, students completed a pre-experience survey (see Appendix A). The pre- survey asked students to complete a self-assessment of their experience, knowledge and skills at the beginning of the summer research experience. Students were also asked to rate their organizational and interpersonal skills, and their familiarity with graduate school application processes. Another set of questions asked students about their expectations for what their summer research experience would involve (e.g., lab-based work versus field work) and what tasks they expected (e.g., gathering data, writing reports, working in a team). The pre-experience survey was intended to capture students' perceptions, skills and knowledge at the beginning of the summer in order to provide a baseline for comparison at the end of the 10-week program.

In the final week of the program, participants completed a post-experience survey designed to identify changes in knowledge, abilities, skills or perceptions related to the research experience (see Appendix B). The post-survey repeated several questions from the pre-survey, and asked

additional questions about students' perceptions and overall impressions of their summer research experience. In addition to the pre- and post-experience surveys, students completed anonymous evaluations of the professional development, writing and networking activities. These questionnaires asked students about their interest in the topic or event, their evaluations of presenters and presentation materials, and their assessment of the overall value of the seminars, workshops, networking events, outreach activities, and writing assignments.

In developing the pre- and post-experience surveys, we were guided by elements of the NSSE (National Survey of Student Engagement) Deep/Integrative Learning Scale. This scale identifies some of the practices or experiences that can deeply impact students' learning, such as "synthesizing and organizing ideas, information, or experience," "making judgments about the value of information," or "applying theories to practical problems or in new situations." We were also informed by previous research on developing and assessing undergraduate research programs.[9,10,12,21–23]

Assessment Results

Forty-eight students (96%) completed both the pre- and post-experience surveys. Comparing the pre- and post-survey results indicates modest gains in students' understanding of research processes, research literature, and research techniques/skills during the course of the 10-week summer experience (Table 2). This result is consistent with existing research that participating in undergraduate research can help students gain both content and process knowledge.[6,11,24]

Table 2: Students' Familiarity with their Research Area

Survey Question Scale: 5=Strongly Agree, 4=Agree, 3=Undecided, 2=Disagree, 1=Strongly Disagree	**Pre-Survey Average**	**Post-Survey Average**	**Change**
I am familiar with the process of research in this area.	3.7	4.2	0.6
I am familiar with the research literature in this area.	3.3	3.9	0.6
I am familiar with the research skills and/or lab techniques in this area.	3.7	4.2	0.6

In addition to assessing their familiarity with the research area/topic that they focused on during the summer program, students were asked about their broader knowledge, abilities and skills. The extant research clearly indicates that participating in research can improve undergraduates' self-efficacy in STEM, although these improvements may vary depending on students' prior experience with research.[9,11,24] Table 3 summarizes students' responses to various self-efficacy assessments, which show little change in the average response on the pre- and post-surveys for most questions. This is not necessarily surprising, given that more than 60% of participants had research experience prior to the summer program.

Table 3: Students' Knowledge, Abilities and Skills

Survey Question Scale: 5=Strongly Agree, 4=Agree, 3=Undecided, 2=Disagree, 1=Strongly Disagree	**Pre-Survey Average**	**Post-Survey Average**	**Change**
I have strong leadership skills.	4.1	4.2	0.1
I have strong interpersonal (social) skills.	3.9	4.1	0.1
I am able to develop a professional network.	3.7	3.9	0.2
I am able to communicate within my discipline.	4.2	4.2	0.0
I am able to communicate across disciplines.	3.8	3.9	0.1
I am familiar with the grad school application process.	**2.3**	**4.2**	**1.9**
I am able to write a concise research abstract.	3.4	4.1	0.7
I am able to create a research poster.	3.6	4.3	0.7
I am able to give an oral research presentation.	3.9	4.1	0.2
I am able to work effectively with others	4.5	4.5	0.0
I am able to work independently	4.6	4.5	-0.1
I am able to manage my time	4.5	4.4	-0.1
I am able to overcome obstacles	4.4	4.4	0.1
I am able to do statistical analysis.	3.9	3.9	0.0
I am able to read, interpret and use research information.	4.2	4.3	0.1

The pre- and post-survey data does indicate that we achieved the goal of making students more aware of graduate school options. More specifically, while just 17% of students in the pre-survey indicated that they were familiar with graduate school application processes, on the post-survey 85% of the participants reported that they were familiar with this process. Students' anonymous feedback about the writing assignments also indicated that they placed a high value on drafting statements that could be used in graduate school applications. For instance, 88% of students agreed/strongly agreed that preparing an academic resume and an academic statement was a valuable learning experience; while 75% agreed/strongly agreed that it was valuable to prepare a personal statement.

We were somewhat surprised to learn from the anonymous feedback that only 67% of the students found the research statement assignment valuable. A review of students' written comments indicated that many felt they did not have a sufficient basis to write a comprehensive research statement, which is not surprising given the limited timeframe of the summer program and variations in students' prior research experience. Overall, however, the students' survey responses and anonymous feedback suggest that the workshops on graduate school and the writing assignments were helpful in developing students' understanding of the graduate school application process.

The pre- and post-survey results (Table 3) also show modest gains in students' assessment of their ability to write a concise research abstract and to create a research poster. These survey results correlate with students' feedback on the requirement that they create a research abstract and research poster as part of their summer experience. More specifically, 77% of the students agreed/strongly agreed that preparing their research abstract was a valuable learning activity, and 90% of the students agreed/strongly agreed that preparing their research poster was a valuable learning activity.

The pre-experience survey also asked students to indicate what they expected to do as part of their research project, while the post-experience survey followed up by asking about students' actual experiences. These questions were intended in part to assess whether improvements to the program website and advertising materials were successful in communicating to students that this was an intensive research experience designed to introduce them to graduate studies. Overall, students had appropriate expectations of the types of tasks involved in Engineering research, although many students overestimated how much they would be able to accomplish during a 10-week program. For instance, about 90% of students expected to analyze data but only 79% of students reported that they actually participated in data analysis during the summer program. In the free-form comments on the post-experience survey, several students mentioned that they ran out of time to complete their experiments or analysis, or that they planned to continue their research during the academic year. Table 4 summarizes the data on students' expectations and actual experiences during the summer program.

The pre- and post-experience surveys also asked students about their plans for after graduation. At the beginning of the summer, 35 students (73%) indicated that they planned on attending graduate or professional school. On the post-experience survey, 46 students (96%) indicated that they intended to pursue graduate or professional studies. The post-experience survey also asked about students' overall experiences during the summer research experience. In response to yes/no questions on the post-experience survey, 47 of the 48 students reported that they intended to pursue another faculty-mentored research experience, and 42% reported that they expected to publish the results of their summer research. Students were also asked on the post-experience survey to assess the impact of the research program on their research skills, preparation for graduate study, and career goals. Overall, students found the program to be valuable; Table 5 summarizes these responses, which align with similar research findings.[2,9,21,24]

Table 4: Students' Expectations and Experiences

Research Process Component/Task	Number of Students who Expected (Pre-Survey)	Number of Students who Experienced (Post-Survey)	Difference
Defining a research problem	29	36	7
Developing a research hypothesis	23	23	0
Designing an experiment	29	26	-3
Gathering data	41	41	0
Analyzing data	44	38	-6
Modeling data	28	21	-7
Writing about research process/results	40	36	-4
Presenting research process/results	40	36	-4
Working in a research group or team	34	36	2
"Bench science" in a laboratory setting	26	28	2
Work in an office setting	18	22	4
Field work outside of an office setting	5	6	1
Developing/using databases	16	12	-4
Developing/using spreadsheets	32	26	-6
Developing websites	0	1	1
Developing computer programs	11	15	4
Computational analysis	23	23	0
Statistical analysis	17	16	-1

Table 5: Students' Overall Impressions of the Summer Research Experience

Survey Question Scale: 5=Strongly Agree, 3=Undecided, 1=Strongly Disagree	**Post-Survey Average**
This experience improved my research skills.	4.6
This experience helped prepare me for graduate study.	4.5
This experience increased my interest in graduate study.	4.2
This experience helped define my career goals.	3.6
I would recommend this experience to other students.	4.5
This program was a valuable way to spend my summer.	4.6

Discussion and Future Plans

While the overall feedback on the professional development activities was positive, students suggested that the sequencing of seminars and workshops should be adjusted to provide a better framework for the writing assignments. For instance, students suggested that the workshop on the graduate school application process be moved earlier, before students begin working on their writing assignments. The students were most interested in the presentations on engineering careers in academia and in industry, developing a research poster, and the graduate school application process. Students were generally less interested in the seminars on research outside their majors/areas. Rather than eliminating these topics, we plan to increase discussions on the importance of multidisciplinary perspectives and ask students to take a more active role by identifying elements of seminars/workshops that could be applied to their own research.

Students' feedback on the writing statements was that they found it helpful to draft materials for graduate school applications (academic resume, academic statement, personal statement). However, most students felt they lacked the necessary experience to write the assigned research statement, and the actual research statements were very uneven in quality, content and depth. For next year, we will experiment with alternatives to the research statement, such as having student blog about their research experiences, or preparing an extended abstract or brief research paper linked to their poster presentation.

Faculty and students also raised some concerns about the timing and method of the program application and matching process. For the last several years, students have submitted applications in February and have included a brief statement about their research interests. These application materials are forwarded to faculty in March, but the actual review and hiring process often takes several weeks. Many excellent students apply to our summer research program but withdraw during the matching process because they have received an industry internship and need to ensure they are employed during the summer. Other students specify general interests (e.g., Mechanical Engineering, nanotechnology) on their application materials and receive offers from faculty who work in that broad area, but whose specific research is not of interest to the student. Consequently, the matching process often requires multiple iterations and does not always result in the most effective faculty-student pairings.

We have adjusted the application process for next year in an attempt to address some of these concerns. For the 2012 program, faculty are asked to submit brief (1-2 paragraph) project descriptions in advance so that students have an opportunity to review available projects online

before deciding to apply to the program. Faculty and students may also develop a joint proposal, where they identify an appropriate research project and submit linked applications to participate in the summer program as a mentor-mentee pair. The hope is that these changes will result in better matches between students' interests and faculty research projects, and allow mentor-mentee pairs to be identified earlier in the process to facilitate summer planning by faculty and students. In the longer term, the program coordinators plan to shift part of the application and selection process to the fall semester, so that highly motivated students could secure a summer research internship early. This would align with the fall career fairs at our university, where many students identify their summer internships, and will hopefully make the summer research experience a more competitive option for students. (A portion of the internships would be reserved for matches identified later in the year, in order to maintain flexibility in the program.)

In addition to these planned adjustments to the application process and writing assignments, we are interested in exploring the experiences of the faculty mentors. Our summer research program involved about 50 faculty mentors in 2011, and we expect to expand to at least 60 faculty and 65+ students in 2012. With this large cohort, we are interested in implementing pre- and post-experience surveys of faculty to better understand their motivations, expectations, and experiences in working with undergraduate research assistants.

References

1. Hathaway RS, Nagda BA, Gregerman SR. The Relationship of Undergraduate Research Participation to Graduate and Professional Education Pursuit: An Empirical Study. Journal of College Student Development. 2002;43(5):614–31.

2. Lopatto D. Undergraduate Research Experiences Support Science Career Decisions and Active Learning. CBE Life Sci Educ. 2007;6(4):297–306.

3. Narayanan R. Use of Objective-Based Undergraduate Research Project Experience as a Graduate Student Recruitment Tool. Journal of Engineering Education. 1999 Jul;88(3):361–5.

4. Dotterer RL. Student-faculty collaborations, undergraduate research, and collaboration as an administrative model. New Directions for Teaching and Learning. 2002 Jun 1;2002(90):81–90.

5. Kuh GD. High-impact educational practices: what they are, who has access to them, and why they matter. Association of American Colleges and Universities; 2008.

6. Kinkead J. Learning Through Inquiry: An Overview of Undergraduate Research. New Directions for Teaching and Learning. 2003 Mar 1;2003(93):5–18.

7. Grimberg S, Langen T, Compeau L, Powers S. A Theme-Based Seminar on Environmental Sustainability Improves Participant Satisfaction in an Undergraduate Summer Research Program. Journal of Engineering Education. 2008 Jan;97(1):95–103.

8. National Science Foundation. Program Solicitation NSF 09-598 (Research Experiences for Undergraduates Sites and Supplements) [Internet]. 2009 [cited 2012 Jan 10]. Available from: http://www.nsf.gov/pubs/2009/nsf09598/nsf09598.pdf

9. Hunter A-B, Laursen SL, Seymour E. Becoming a Scientist: The Role of Undergraduate Research in Students' Cognitive, Personal, and Professional Development. Science Education. 2007 Jan;91(1):36–74.

10. Lopatto D. Survey of Undergraduate Research Experiences (SURE): First Findings. Cell Biology Education. 2004 Winter;3(4):270 –277.

11. Lopatto D. Science in Solution: The Impact of Undergraduate Research on Student Learning. Research Corporation for Science Advancement; 2009.

12. Seymour E, Hunter A-B, Laursen SL, DeAntoni T. Establishing the Benefits of Research Experiences for Undergraduates in the Sciences: First Findings from a Three-Year Study. Science Education. 2007 Jul;88(4):493–534.

13. Bauer KW, Bennett JS. Alumni Perceptions Used to Assess Undergraduate Research Experience. The Journal of Higher Education. 2003;74(2):210–30.

14. Hurtado S, Cabrera NL, Lin MH, Arellano L, Espinosa LL. Diversifying Science: Underrepresented Student Experiences in Structured Research Programs. Research in Higher Education. 2008;50(2):189–214.

15. Resnick ML, Centeno MA, Giachetti R. Research Experience for Undergraduates--Motivating and Retaining Bright Engineering Students. Proceedings of the Annual Meeting of the Human Factors and Ergonomics Society. 2000;2:79.

16. Baker S, Tancred P, Whitesides S. Gender and graduate school: Engineering students confront life after the B. Eng. Journal of Engineering Education. 2002;(January):41–7.

17. Chesler MA. Gender-Informed Mentoring Strategies for Women Engineering Scholars: On Establishing a Caring Community. Journal of Engineering Education. 2002;91(1):49–55.

18. Karukstis KK, Gourley BL, Wright LL, Rossi M. Mentoring Strategies To Recruit and Advance Women in Science and Engineering. Journal of Chemical Education. 2010;87(4):355–6.

19. Dahlberg T, Barnes T, Rorrer A, Powell E, Cairco L. Improving retention and graduate recruitment through immersive research experiences for undergraduates. SIGCSE Bull. 2008 Mar;40(1):466–70.

20. National Science Foundation. NSF Graduate Research Fellowship Program [Internet]. [cited 2012 Jan 10]. Available from: https://www.fastlane.nsf.gov/grfp/Login.do

21. Kardash CM. Evaluation of undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. Journal of Educational Psychology. 2000;92(1):191–201.

22. Nelson Laird TF, Shoup R, Kuh GD, Schwarz MJ. The Effects of Discipline on Deep Approaches to Student Learning and College Outcomes. Research in Higher Education. 2008;49(6):469–94.

23. Labrador MA, Pérez R. Fulfilling Mentors' Expectations: An REU Site Experience. Proceedings of the Southeast Section Conference of the American Society for Engineering Education. 2006.

24. Li S, Wang Y, Moss E. The Effectiveness of the REU Program Among Novice Undergraduates. The Business Review, Cambridge. 2010 Dec;16(2):334–40.

APPENDIX A: Student Participant Pre-Experience Survey

Name: _____

Please indicate your ethnicity by checking **all that apply:**

- ☐ International Student
- ☐ American Indian or Alaskan Native
- ☐ Asian
- ☐ Black or African American
- ☐ Caucasian
- ☐ Chicano
- ☐ Hawaiian or Pacific Islander
- ☐ Hispanic
- ☐ Other: _____

Please consider the **area of research you are working in this summer**, and indicate your level of agreement with each of the following statements:

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
I am familiar with the process of research in this area.					
I am familiar with the research literature in this area.					
I am familiar with the research skills and/or lab techniques in this area.					

Please consider **your current knowledge, abilities or skills** and indicate your level of agreement with each of the following statements:

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
I have strong leadership skills.					
I have strong interpersonal (social) skills.					
I am able to develop a professional network.					
I am able to communicate within my discipline.					
I am able to communicate across disciplines.					
I am familiar with the grad school application process.					
I am able to write a concise research abstract.					
I am able to create a research poster.					
I am able to give an oral research presentation.					
I am able to work effectively with others					
I am able to work independently					
I am able to manage my time					
I am able to overcome obstacles					
I am able to do statistical analysis.					
I am able to read, interpret and use research information.					

	Yes	**No**
Is this summer your first faculty-mentored research experience?	☐	☐
Have you previously published any research in a journal or conference proceedings?	☐	☐
Have you previously presented any research in an oral or poster format?	☐	☐
Have you taken the GRE?	☐	☐
Do you plan to take/retake the GRE this summer or fall?	☐	☐
Did you know your summer faculty mentor prior to this research experience?	☐	☐
Have you already talked to your faculty mentor about what you'll do this summer?	☐	☐

What do you expect to do as part of your summer research experience? Check **all that apply:**

- ☐ Defining a research problem
- ☐ Developing a research hypothesis
- ☐ Designing an experiment
- ☐ Gathering data
- ☐ Analyzing data
- ☐ Modeling data
- ☐ Writing about research process/results
- ☐ Presenting research process/results
- ☐ Working in a research group or team
- ☐ "Bench science" in a laboratory setting
- ☐ Work in an office setting
- ☐ Field work outside of an office setting
- ☐ Developing/using databases
- ☐ Developing/using spreadsheets
- ☐ Developing websites
- ☐ Developing computer programs
- ☐ Computational analysis
- ☐ Statistical analysis
- ☐ Other: _____

Please indicate your current plans for after graduation**:**

- ☐ Work in an Engineering-related area
- ☐ Work in another area
- ☐ Study or work abroad
- ☐ I have no idea
- ☐ Attend Graduate School (MS or PhD)
- ☐ Attend Professional School (medical, law, etc.)
- ☐ Other: _____

Why did you choose to participate in this undergraduate research experience? Check **all that apply:**

- ☐ To help prepare me for graduate school
- ☐ It was a paid position
- ☐ It will enhance my resume
- ☐ To develop a mentoring relationship with a faculty member
- ☐ A faculty/staff member approached me about the opportunity
- ☐ To gain practical experience for a future career
- ☐ It sounded interesting
- ☐ Other: _____

How did you learn about this undergraduate research experience? Check **all that apply:**

- ☐ MSU Engineering Faculty
- ☐ Other MSU Faculty or Staff
- ☐ Email Announcement
- ☐ MSU Engineering Academic Advisor
- ☐ Program Website
- ☐ Other:_____

If you were not participating in this research experience, what would you be doing this summer instead?

What knowledge or skills do you hope to gain from your summer research experience?

What specific topics or information do you hope will be covered as part of the professional development activities during this summer research experience?

APPENDIX B: Student Participant Post-Experience Survey

Name: _____

Please consider the **area of research you worked in this summer**, and indicate your level of agreement with each of the following statements:

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
I am familiar with the process of research in this area.					
I am familiar with the research literature in this area.					
I am familiar with the research skills and/or lab techniques in this area.					

Please consider **your current knowledge, abilities or skills** and indicate your level of agreement with each of the following statements:

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
I have strong leadership skills.					
I have strong interpersonal (social) skills.					
I am able to develop a professional network.					
I am able to communicate within my discipline.					
I am able to communicate across disciplines.					
I am familiar with the grad school application process.					
I am able to write a concise research abstract.					
I am able to create a research poster.					
I am able to give an oral research presentation.					
I am able to work effectively with others					
I am able to work independently					
I am able to manage my time					
I am able to overcome obstacles					
I am able to do statistical analysis.					
I am able to read, interpret and use research information.					

Please consider **your overall impression of the summer research program** and indicate your level of agreement with each of the following statements:

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
This experience improved my research skills.					
This experience helped prepare me for graduate study.					
This experience increased my interest in graduate study.					
This experience helped define my career goals.					
I would recommend this experience to other students.					
This program was a valuable way to spend my summer.					

	Yes	**No**
Do you intend to pursue another faculty-mentored research experience in the future?	☐	☐
Will you publish your summer research in a journal or conference proceedings?	☐	☐
Have you taken the GRE?	☐	☐
Do you plan to take/retake the GRE this fall?	☐	☐
Did you keep a research notebook this summer?	☐	☐

What have you done as part of your summer research experience? Check **all that apply:**

- ☐ Defining a research problem
- ☐ Developing a research hypothesis
- ☐ Designing an experiment
- ☐ Gathering data
- ☐ Analyzing data
- ☐ Modeling data
- ☐ Writing about research process/results
- ☐ Presenting research process/results
- ☐ Working in a research group or team
- ☐ "Bench science" in a laboratory setting
- ☐ Work in an office setting
- ☐ Field work outside of an office setting
- ☐ Developing/using databases
- ☐ Developing/using spreadsheets
- ☐ Developing websites
- ☐ Developing computer programs
- ☐ Computational analysis
- ☐ Statistical analysis
- ☐ Other: _____

Please indicate your current plans for after graduation**:**

- ☐ Work in an Engineering-related area
- ☐ Work in another area
- ☐ Study or work abroad
- ☐ I have no idea
- ☐ Attend Graduate School (MS or PhD)
- ☐ Attend Professional School (medical, law, etc.)
- ☐ Other: _____

What part(s) of the summer program did you find **most** valuable or helpful?

What part(s) of the summer program did you find **least** valuable or helpful?

Please share any additional comments, suggestions for changes, or feedback about the summer program.