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# Research for Undergraduates experiences from various academic institutions

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# Research for Undergraduates: Experiences from various academic institutions

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## Abstract

The opportunities for doing research by undergraduate freshmen students help them to pursue further career interests in Science, Technology, Engineering, and Mathematics (STEM) field. Involving undergraduate students in research will make them take more interest in studies and motivate them to pursue graduate degrees. The undergraduate students at Pennsylvania State University where I teach get involved in research usually conducted in the summer period for an 8-week or 10-week duration. The name of the program is "Multi-campus Research Experience for Undergraduates" (MC-REU) and it is administered by the College of Engineering at Penn State.

Similarly, there are many academic institutions in the United States that got involved with research undertaken by undergraduate students. The goals of the undergraduate research programs are (1) to promote undergraduate students participating in research early in their academic program to broaden their education and increase their chances of entering graduate studies, (2) to promote mutual awareness and collaboration among faculty across the various units and disciplines that offer undergraduate research programs, and (3) paves way for new faculty go get involved with research early in their career.

This paper will explain some of the exposures of the "Research Experience for Undergraduates" (REU) (as case studies) from different institutions and draw conclusions based on the students' feedback from various educational institutions. Usually, students will not take any courses towards their academic accomplishments during the summer when they are engaged in research. They will work 40 hours per week for the 10-week or 8-week period during the summer.

## Introduction

Engineering Departments at Universities have undertaken the "Research for Undergraduate students" seriously in the recent past so that some of the institutions where there are no graduate students can also engage in research. Generally, the research experience will develop the organizational skills, communication, teamwork, and high-level cerebral activity within the minds of students (Zydney et al., 2002). Also, the undergraduate research experience creates immense confidence among students and inculcates the habit of seeking higher education in their respected chosen fields (Narayanan, 1999).

Most of the students that go through the undergraduate research experience end up in graduate schools of various universities such as Purdue University, University of Puerto Rico, University of South Florida, and the University of Illinois at Urbana-Champaign. Some of them end up working for US Corps of Engineers national laboratories (Acosta, 2004).

Involvement in Undergraduate Research Experiences (URE) is related to considerably increased persistence and improved academic performance of students in science, technology, engineering, and mathematics (STEM) disciplines. UREs have shown to promote students' sense of project ownership, self-effectiveness, and scientific identity. The advantages derived from URE have a very good impact on minority students and their improved STEM retention (Vater, 2019).

**Case Studies:**

**Case study 1: University of Cincinnati Structural Engineering Projects**

Research Experiences for Undergraduates (REU) website was developed to accommodate a few "Structural Engineering projects" (funded by the National Science Foundation, NSF) in the Civil & Environmental Engineering Department of the University of Cincinnati (UC). The website, hereafter will be called "Site" allows nine students to participate after a rigorous selection process. Five of them were selected from UC, four of them were selected from outside the UC, including one Native American male, three women, one Hispanic male, three white American male students, and one African American male. A Project Director, a Faculty Mentor, one Graduate Student Mentor (Research Assistant), and a Lab Technician assist.

The research experience provided was in the area of structural engineering. Nine students were selected to participate in the Site; four students selected were from institutions outside Cincinnati, and five were selected from UC. These included three women, one Native American male, one Hispanic male, one African American male, and three white American male students, and each group worked on a separate project during the two summer months. Each group were supervised by the Project Director (author) and a Faculty Mentor, one Graduate Student Mentor (Research Assistant), and a Lab Technician during the complete duration of the REU Site. The whole research program was planned and conducted, the details of the projects selected for the students, and procedures were used to evaluate the impact of the project. This study will help others in planning similar experiences for engineering undergraduate students.

The purpose of this REU Site was to encourage talented undergraduates to enroll in graduate school by exposing them to research and increasing their interest in graduate research. In this case study, first the basic approach adopted to plan the REU Site and associated activities are presented in its first section, followed by a detailed description of the projects executed. In the end, evaluation procedures used, the lessons learned, and the outcomes from the whole experience are summarized. One of the students commented on the technical writing skill that he gained from the REU experience and felt that was very useful in his Solid Mechanics Laboratory course to write laboratory reports (Anant, 2002).

**Case study 2: Course-based Undergraduate Research Experiences (CUREs)**

The student's retention in STEM disciplines is associated with more hands-on activities than simply studying using only books. The research opportunities will help the undergraduate students to understand the subject matter in a deeper sense and lead scientific endeavors of the 21$^{st}$ century. Large universities provide a lot of opportunities to undergraduate students to pursue research in a chosen field, while small and medium-sized universities are struggling to provide opportunities to undergraduate students. Course-based undergraduate research experiences (CUREs) provide an expansive solution to this problem by facilitating faculty-mentored student research on unique problems through the structure of unit-bearing classes. It was investigated whether First-Year Seminars (FYS), small credit-bearing classes targeted at the freshman and transfer students, which are common in large universities, could provide a venue for CUREs. And it seems students demonstrated attitudinal gains related to STEM retention after CUREs are introduced.

Summary of FYS program at UC Davis

First-year seminar courses at UC Davis have been part of the curriculum since 1978, have their course codes, and are purely elective courses that can be letter-graded or Pass/No-Pass graded for one or two units. Students are limited to one FYS per ten-week quarter, and students with first-year status (including transfer students) are given priority registration. The program is reviewed regularly by the Special Academic Program committee of the Academic Senate Undergraduate Council.

Teaching structure and FYS-CUREs were supported centrally by the FYS program's academic coordinator responsible for experiential FYS, who has training in CURE pedagogy and instruction. The academic coordinator offered support for administrative and academic activities, including ensuring the availability of required laboratory equipment and space, supplies ordering, coordinating best practices across CUREs, and in some instances serving as a co-instructor. Guidance and individual training in the design and assessment of new CUREs were offered to the faculty. Instructors were encouraged to use student-centered teaching techniques such as active learning strategies and backward course design to further promote the success of FYS-CUREs. Undergraduate researchers in the laboratory of faculty instructors, Learning Assistants, and students were provided internship units for their work as part of the instructional team.

Graduate students or postdoctoral fellows, and staff as part of the instructional teams having faculty as instructors of record taught the FYS base CUREs (FYS-CUREs). FYS based CUREs (FYS-CUREs) were offered as 2-unit, letter-graded courses, meeting for two consecutive hours each week for 10 weeks.

FYS-CUREs enrollment was managed on a first-come, first-served basis, and seats were initially reserved for both freshmen and incoming transfer students. All lab notebooks were maintained as live documents on Google Drive and course materials were posted on the university online course management system. An end-of-term project was assigned, which aggregated, organized, and distributed the data collected in class to contribute to the collaborating PI's research mission. While the interrelated-course elements were minimally coordinated, all sections used the same Pre-Post-survey and included the same learning goals in their syllabi.

Student assessments

Twenty biology-related seminars were offered by the FYS-CURE program in the academic years of 2016-17 and 2017-18; students were surveyed on the first and the last days of the quarter. Students reported a sense of belonging in science, instructor access, collaboration importance, and a better understanding of the research process. They also felt that it was very enjoyable and personal, hands-on, and keeping clarity on career-related paths.

UC, Davis despite their limitations, through these courses was able to provide authentic research experiences to around 300 students who otherwise would have not engaged in research. These students by and large also represented the rich diversity of the undergraduate student body at UC Davis. Thus, even at this relatively small scale, the implementation of CUREs in the First Year Seminar Program has contributed to UC Davis's goal of providing all interested students with research opportunities. Furthermore, the initial results from implementing FYS-CUREs can be used by institutions to seek additional funding and motivate significant curricular re-designs (Vater, 20219).

**Case study 3: Drexel University REU**

Program Assessment of Engineering Cities

Drexel University established "The Engineering Cities REU (Research Experience for Undergraduate students) site to address the needs of the urban areas with the help of qualified engineers who can deal with the unique urban growth challenges. Recognizing these challenges, the primary goals of the *Engineering Cities* site are to:

1) Students' motivation to pursue advanced degrees in engineering.

2) Improving students' research skills and encouraging creative thinking in a laboratory or analytical setting.

3) Developing well-trained, highly qualified candidates for the nation's graduate programs.

4) Encouraging students to pursue careers serving the urban community after completion of their graduate studies.

5) Encouraging the extended participation of students enrolled in co-op education programs.

A total of twelve students are selected annually for the program. Of the twelve students, two are six-month co-op participants and ten are ten-week summer participants.

Most of the world's population is living in urban centers for the first time in history. While the growth of cities offers many benefits for society, the rates of growth currently taking place pose an array of unique challenges to those who engineer the urban environment. Key concepts among these challenges are developing and renewing the urban infrastructure, promoting sustainable growth and ensuring environmental quality, and protecting populations from natural and anthropogenic hazards.

This study reports on the assessment results for the ten-week program students only. Recruitment efforts are directed at individuals from underrepresented groups and individuals who do not have access to advanced research facilities at their home institutions. The REU experience consists primarily of an intensive research experience in which each student works closely with a predetermined faculty mentor and her/his research group on a specific research problem. Students who participate in the program work as integral members of the faculty mentors' research team. Additionally, each student is paired with a graduate student who guides the day-to-day activities of the REU participant. Each REU student has weekly research meetings with his/her respective faculty mentor.

Since the primary objective of the program is to improve students' research and creative abilities, the REU experience is designed to encourage the development of key skills that will serve participants throughout their careers. Those key skills may include

(1). Identification of a research problem, literature review methodology, and critical review of the Literature.

(2). Design and implementation of a research plan and timeline.

(3). Conducting research, including learning new methods, analysis procedures, and/or skills.

(4). Dissemination of the results in both written and oral forms.

The development of these skills has the indirect effect of increasing student confidence, improving critical thinking and problem-solving abilities, and enhancing both verbal and written communication skills. In addition to providing a meaningful research experience, the site includes a variety of enrichment and professional development activities that allows students to better appreciate the inherent complexities of urban engineering and to explore the broader social and political implications of their work.

Enrichment activities include an ethics workshop, a seminar series on urbanism, a reading group, and field trips focused on urban policy and managing the urban infrastructure.

REU program efficacy can be framed by summarizing student perceptions of the REU program in three areas: faculty, research experiences, and future orientation/ program results. Overall, students had positive perceptions of their faculty experiences; however, three students expressed difficulties with the disposition and frequency of contact with their faculty members. This finding runs contrary to faculty expression of the importance of regular communication between mentor and student. This translated into these students not feeling a part of the team, not feeling comfortable asking questions, and not developing a mentor relationship with these faculty.

While most students reported positive research experiences, as stated previously, many did not have the opportunity to co-author, publish, or learn more about publishing a scientific paper. This is an interesting finding as this desire was rated somewhat highly among the needs and references of the students at the start of the program. One-third of the student respondents felt that the program did not stimulate curiosity and enthusiasm about research in engineering. This finding is not conducive to the accomplishment of one of the program's primary objectives—motivating students to pursue advanced degrees in engineering. A small majority of students rated the REU program positively on project results and their future orientation upon exit, while 88% of the students expressed enthusiasm regarding the pursuit of an advanced degree in engineering. Several student respondents (45%) were not fully convinced that they would be interested in continuing work on their REU project. These are important findings as one of the REU program's biggest objectives is motivating students to pursue advanced degrees in engineering.

**Case study 4: Two Universities and the REU program**

Smart Structures Technologies (SST), which includes advanced sensing, modern control, smart materials, Optimization, and novel testing, is receiving considerable attention as it has the potential to transform many fields in engineering, including civil, mechanical, aerospace, and geotechnical engineering. Currently, there is a significant gap between the engineering and science with fundamental research in academia and engineering practice with potential application in the industry. To respond to this challenge, San Francisco State University and the University of South Carolina collaborated with industrial partners to establish a Research Experiences for Undergraduates (REU) Site program, focusing on academia-industry collaborations in SST.

This REU program will train undergraduate students to serve as the catalysts to facilitate the research infusion between academic and industrial partners. This student-driven joint venture between academia and industry will establish a virtuous circle for knowledge exchange and contribute to advancing both fundamental research and implementation of SST. The program will feature: formal training, workshops, and supplemental activities in the conduct of research in academia and industry; innovative research experience through engagement in projects with scientific and practical merits in both academic and industrial environments; experience in conducting laboratory experiments: and opportunities to present the research outcomes to the broader community at professional settings. This REU program will provide engineering undergraduate students with a unique research experience in both academic and industrial settings through cooperative research projects. Experiencing research in both worlds is expected to help students

transition from relatively dependent status to independent status as their competence level increases.

The joint efforts among two institutions and industry partners provide the project team with extensive access to valuable resources, such as expertise to offer a wider range of informative training workshops, advanced equipment, valuable data sets, experienced undergraduate mentors, and professional connections, that will facilitate a meaningful REU experience. Recruitment of participants will target 20 collaborating minority and primarily undergraduate institutions (15 of them are Hispanic-Serving Institutions, HSI) with limited science, technology, engineering, and mathematics (STEM) research capabilities. The model developed through the program may help to exemplify the establishment of a sustainable collaboration model between academia and industry that helps address the nation's need for mature, independent, informed, and globally competitive STEM professionals and is adapted to other disciplines (Zhaoshuo).

**Case study 5: University of Alabama at Birmingham REU program**

A summer Research Experiences for Undergraduates site in structural engineering, funded by the National Science Foundation, has operated at the University of Alabama at Birmingham for the past seven years. During this time, 33 students from 22 colleges and universities have participated in the site. Participants are recruited nationally and have come from as far away as California and Puerto Rico. The program is intended to provide students interested in graduate studies with an introduction to research methods, and to provide students who will not continue their studies past a Bachelor of Science in civil engineering with a better understanding of how research provides the theoretical foundation of engineering practice. Students work individually with faculty on literature reviews, computer modeling, laboratory testing, and field research. Three students have researched structural failure case studies and the technical and ethical lessons to be learned from them. Participants also have the opportunity to tour construction sites and construction material manufacturers and fabricators' facilities. During the past three years, an ethics seminar series has been added. At the end of the program, students prepare research papers and Web pages documenting their work and present their results to faculty, students, and other participants.

The student work has enhanced the breadth and depth of research underway at the host campus, and has paved the way for expansion into new areas of research for faculty. Survey results have consistently shown that participants consider this a valuable and useful experience. Many of the past program participants have gone on to graduate school at UAB or elsewhere. Three prior participants were employed full-time as graduate research assistants at UAB during the 2000–2001 academic year.

Participants are asked to evaluate the program each year in order to improve it. The program participants are surveyed on arrival, on departure, and approximately six months after leaving. Survey questions on a five-point scale (1 = low to 5 = high) are adopted for evaluation.

The survey results indicate that the students have strong confidence in their abilities to complete their undergraduate programs. This is not affected much by the program. Most students recruited for the program are capable and well committed to their undergraduate degree programs. Results on encouraging students to continue on for a Master of Science degree are mixed. Although the survey is anonymous, there is some indication that there is a rough balance between students who had planned to continue on to graduate school and decide not to, and those who had not planned to continue, but change their minds. Therefore, although the program may not be bringing more students into graduate school, it may be helping the right students identify themselves. It should be noted that these years cover a time when many engineering graduates could count on receiving many attractive job offers, making graduate study less enticing. In the present cooling economy, this may change.

The desire to continue on for a doctorate degree decreased slightly. This tendency was low, to begin with, and the small number of students expressing a desire to study for a doctorate at the beginning of the program may not have realized the level of effort involved before undertaking their own independent research. On the other hand, research skills and recognition of their importance went up significantly, as did the confidence of the participants. The understanding of the importance of ethics also increased, with respect to both research and professional practice. Overall, the students saw the value of the ethics component of the REU site.

**Case study 6: Yakima Valley College "Summer Undergraduate Research Experiences" program**

Yakima Valley College (YVC) a two-year, Hispanic-serving institution in south-central Washington state partnered with four-year universities, agricultural centers, businesses, and federal and state agencies to develop a streamlined undergraduate research experience in which students work closely with a faculty mentor in science, technology, engineering, or mathematics (STEM) field on summer projects of 120 hours each. Assessment metrics reveal high transfer, graduation, and/or continued enrollment rates for research participants as well as increased student perceptions in thinking and working like a scientist, personal gains related to research work, and skills. Faculty also benefited as indicated by high rates of return to the program. This article reviews the importance of multiple stakeholders in program development, including the essential role of university and community partnerships. The YVC Summer Undergraduate Research Experiences (SURE) program has developed within a context in which the students and faculty have limited time and resources to contribute to a research experience. In contrast to participants in longer, more intensive Undergraduate Research Experiences (UREs) offered at four-year institutions, students and faculty in the YVC SURE program commit 120 hours to a project that lasts from three to seven weeks in the summer.

Faculty develop single-summer projects or mentor individualized segments of multiyear projects. Each project usually has one mentor and two students. Research during the academic year is exceedingly rare; the faculty teach full time with no contractual research expectations. YVC has approximately 30 STEM faculty with core disciplines that include biology, chemistry, computer science, engineering, geosciences, mathematics, nutrition, psychology, and physics. Most "SURE" students are second-year students, although first-year students are eligible to participate in the program. Over the program's length, 194 students have been enrolled. From 2012 to 2019, students earned a $1500 stipend, whereas faculty received a $3000 stipend; in 2020, the student stipend was increased to $1725.

Multiple lessons can be learned from this experience that apply to other two-year institutions. First, the program does not mimic the standard URE common at four-year universities. This design was intentional. The financial burden of paying stipends to students and faculty for a research model of 30+ hours per week for eight weeks would have substantially limited the number of students that could have been accommodated. Moreover, the program design meets the needs of many students who are balancing the demands of summer school, jobs, and family responsibilities. Second, the STEM faculty represent diverse disciplines with different research approaches, and they have significant latitude in designing projects that are challenging and educationally fulfilling. Third, program assessment of student outcomes indicates educational achievements such as high continued enrollment at YVC, transfer and/or graduation rates, as well as self-reported increases in constructs such as "Thinking and Working Like a Scientist," "Personal Gains Related to Research Work," and "Skills."

**Case study 7: Pennsylvania State University MC-REU program**

Multi-Campus Research Experiences for Undergraduates (MC-REU) Program at Pennsylvania State University.

The REU at Penn State University is a "research work involved program" offered in the summer to promote research skills among undergraduate students. It also serves as a vehicle for the faculty to start active research at the commonwealth campuses (there are 20 satellite campuses located in Pennsylvania covering the entire state). The faculty at a commonwealth campus will collaborate with a faculty at University Park (Main campus) for engaging in initial research with the help of undergraduate students. The undergraduate students get the opportunity to do research in engineering disciplines so that they reap the benefits of productive scientific research. At the same time, the faculty at the commonwealth campus gets the opportunity to get into the research arena along with their teaching responsibilities.

The name of the program is "Multi-campus Research Experience for Undergraduates" (MC-REU) and it is administered by the College of Engineering at this institution. This program is run with an 8-week or 10-week project duration during the summer semesters and the students should not register for any courses during the time they get involved in the research. They are paid $4,200 stipend for that 8-week or 10-week period, and the faculty involved at the Main campus as well as at the commonwealth campus get $500 each for research support.

The students who underwent this REU program at Penn State feel that they get the feeling of being working like a scientist, thinking like a scientist, and doing the related activities with vigor and greater efficiency. Eventually it complements their undergraduate program in a big way so that they can complete their course work smoothly with more confidence.

**Summary of Case studies:**

**Case study 1 description**: Consists of 9 students, with 3 projects and 3 students per project. Students' stipend of $1000/month for two months. Also lodging, boarding, and traveling expenditures are covered by the program. Project is guided by Faculty Mentor and a graduate student mentor. Students have to finish a final technical report as the deliverable and also, they have to present their work.

**Case study 2 description**: Consists of 15 students per academic year. REU is included in the First Year Seminar class which runs for 10 weeks. Students take this course as an elective course. Students are selected based on the first come first served basis.

**Case study 3 description**: Consists of 12 students per year worked on 10-week summer program. Each student is paired with a graduate student. The outcome is of writing a report and giving a presentation on their research.

**Case study 4 description**: Consists of 20 students and offered by San Francisco State University, University of South Carolina, and industrial partners. Students conducted laboratory experiments, and industry field work. At the end of the program students make reports and write technical journal papers along with faculty.

**Case study 5 description**: Consists of 33 students from 22 different Universities and Colleges. University of Alabama operates it for the past 7 years. Students also visit construction sites and manufacturing units. It is funded by National Science Foundation. Research papers are produced at the end of the program and students document their work on web pages.

**Case study 6 description**: Summer project with 120 hours of work and students get a stipend of $1750 and faculty get a stipend of $3000. Project report must be submitted as the deliverable.

**Case study 7 description**: Consists of 150 students of 20 commonwealth campuses of Penn State University pairing with the main campus faculty. Student gets a stipend of $4200 per 8-week period or 10-week period. Faculty gets a stipend of $500 each from a commonwealth campus and the main campus. At the end of the period, the student is expected to submit a final report and give a presentation of his/her research work.

**Summary of Students' feedback**

The student's feedback who participated in the undergraduate research programs.

1. REU experience has improved the student's ability to write laboratory reports easily as he/she gained technical writing skills.
2. Students reported a sense of belonging in science, instructor access, collaboration importance, and a better understanding of the research process.
3. They also felt that it was very enjoyable and personal, hands-on, and keeping clarity on career-related paths.
4. Overall, students had positive perceptions of their faculty experiences, however, some students expressed difficulties in communicating with their faculty members.
5. While most students reported positive research experiences, as stated previously, many did not have the opportunity to co-author, publish, or learn more about publishing a scientific paper.
6. The model developed through the REU program may help to exemplify the establishment of a sustainable collaboration model between academia and industry that helps address the nation's need for mature, independent, informed, and globally competitive STEM professionals and is adapted to other disciplines.
7. Students have developed a strong confidence in their abilities to complete their undergraduate programs.
8. Students get the confidence of working on research projects and to do well in their coursework.

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