AC 2010-2361: REU PROGRAM IN TELEMATICS AND CYBER PHYSICAL SYSTEMS: SHARING STRATEGIES, EXPERIENCE AND LESSONS LEARNED TO HELP OTHERS

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REU Program in Telematics and Cyber Physical Systems (TCPS): Sharing Strategies, Experience and Lessons Learned to Help Others

Abstract

During the summer of 2009 we ran an 8-week long NSF funded REU program in Telematics and Cyber Physical Systems. Ten undergraduate students were selected from various institutions around the country. The REU students were supervised by ten graduate student and eight faculty mentors. It was an intensive program as the students were involved in various activities including doing research, writing technical papers, making technical presentations, participating in field trips, writing field trip reports and creating posters for technical sessions. Students were required to attend weekly tutorial sessions where they were taught research methodologies and how to write technical papers and make technical presentations. The students were also required to participate in a final poster competition. Throughout the program, we assessed students' progress and provided them with feedbacks. The students also participated in various types of surveys during the program. Throughout the program, we used the survey results to improve the tutorial sessions so that students could get better research and learning experience during the rest of the program. The main focus of this paper is to share our experience in various activities such as recruiting, organizing, mentoring, monitoring and assessing students' activities with other current and future directors of REU programs so that they can successfully plan for and run their programs. In the paper, we present various assessment results of our program. The paper also presents the lessons that we have learned from this program. Finally, the paper presents recommendations regarding how to organize and run future REU programs by other program directors. We believe that our paper will help future REU program directors to plan ahead and avoid any last minute pitfalls in running the program.

Introduction

Participation in research can promote retention for a variety of reasons. V. Tinto et. al.[1] reported that students often fail to graduate due to a lack of persistence, rather than due to lack of intelligence or ability. Being familiar with "hands-on" technology in a laboratory where they become familiar with current equipment boosts self-confidence[2]. Participation in research groups can promote persistence in a variety of ways, in part by increasing personal attachment to the research group and the research objectives. Secondly, the mentoring process inherent in the relationship between the research supervisor and the student researchers permits identification of problems at critical junctures. Finally, the student researchers can learn important skills that will promote success in other academic activities. These skills include teamwork, written and oral communication skills, interdisciplinary thinking, experimental skills, decision-making and evaluation of competing solutions. In addition, the National Science Foundation has stated that it is important for all undergraduates to have access to research opportunities, an opinion echoed by the Boyer commission[3]. It is well recognized that research experiences for undergraduates (REU) programs are very effective educational tools for enhancing the undergraduate experience[4,5] with various benefits[5,6]. The significant benefit of the REU program is an increased interest in science, technology, engineering, and mathematics (STEM) careers[5-8]. REU fosters

increased persistence in the pursuit of an undergraduate degree[5-9]; increased interest in pursuing graduate education[5-11]; and gains in skills (conducting research, acquiring information, and speaking effectively) by REU alumni over comparison groups[5-12]. REU helps develop career pathways for underrepresented students by increasing minority retention[5-8] and the number of minority students pursuing graduate degrees[5-13]. Similarly, numerous other references could be found that demonstrate the benefits and significance of an REU program. The main focus of our paper is to share our experience and the lessons that we have learned with the others who want to run REU programs.

During the summer of 2009 we ran an REU program in *Telematics and Cyber Physical Systems* (TCPS). This was the first year of our 3-year REU program. Telematics is the blending of computers and communication in automotive systems for automatic roadside assistance, remote diagnosis, and other vehicle information services. A cyber-physical system (CPS) is a system featuring a tight combination of, and coordination between, the system's computational and physical elements. Applications for cyber-physical systems can be found in health care (assisted living, bionics, wearable devices, …), transportation and automotive networks, aerospace and avionics, automated manufacturing, blackout-free electricity generation and distribution, optimization of energy consumption in buildings and vehicles, critical infrastructure monitoring, disaster response, efficient agriculture, environmental science, and personal fitness. The main goal of our program is to provide research experience to the undergraduate students in TCPS. The additional goals of our program are to train the undergraduate students in developing good written and oral communication skills and prepare them to enter into graduate programs. The uniqueness of our program is the area of research for undergraduate students. The other activities of our program are similar to the activities necessary for running any good REU programs.

The success of an REU program depends on advanced planning and active supervision, and monitoring and management of the activities during the program. There are various key components of an REU program. These components include but are not limited to: recruiting, orientation, pairing of students with faculty and graduate student mentors, project assignments, weekly meetings and tutorial sessions, mentoring, evaluation and continuous improvement, field trips, technical presentations and administrative activities.

In the rest of the paper we present detailed descriptions of our activities along with our recommendations and suggestions for running a good and effective REU program.

Components of our REU Program in TCPS

Any good REU program must have a number of key components that must be properly planned, designed, managed and evaluated. These activities require significant amount of time commitment from the people who will be running the program. As a result, advanced planning is very important. The components of our REU program are as follows:

Recruiting*:* It is one of the most important components of an REU program. A good recruitment strategy will enable the program to select the most appropriate candidates the program has been designed for. Recruiting for the first year is the most crucial task because not much time is

available between the time the grant is awarded and the recruiting process should begin. As a first step towards our recruiting activity, we developed a website containing detailed information about our program including *stipend and benefits*; *application process*; *eligibility*; a *description* of the REU activities; *types of projects*; *contact information* of all personnel including faculty mentors, program manager, program coordinator and public safety; *research areas* of all faculty mentors and *links* to their websites. The URL of the program's website was included in the National Science Foundation list of NSF-funded REU Sites[14]. We also developed a flyer containing vital information about the program. Hardcopies of the flyer were mailed to over 50 institutions around the country. The softcopy of the flyer was also emailed to the Department Chair and Undergraduate Program Director of Electrical and Computer Engineering Department and Computer Science Department of over 50 institutions, and we requested the Department Chairs and Undergraduate Program Directors to forward our email to their undergraduate students. This was a very effective way of recruiting, as most of the REU interns said that they heard about our program from the email distribution of their own schools. We also distributed the flyer to our own undergraduate students via email.

Table I: Demographics of our REU Applicants

Gender

Female	4
Male	26

Location

California	1
New York	1
Montana	1
Puerto Rico	3
Michigan	24

Ethnicity

Asian	3
African American	5
Hispanic	2
Pacific Islander	1
White	16
Unknown	3

Academic Standing

Sophomore	4
Junior	9
Senior	17

Institution

Our	11
Other	19

Our recruitment efforts yielded a total of 30 applications. One of the eligibility requirements was 3.0 GPA out of 4.0. All 30 applicants had a GPA of 3.0 or above. The demographics of the applicants are shown in Table I. There were four female and 26 male applicants. Two of the female applicants were African Americans and the other two were Whites. We received only 6 applications from outside our home state Michigan. Despite all those mailing and emailing of our flyer we were unable to receive significant number of applications from outside Michigan compared to what we received from Michigan. One possible reason may be the package that we offered was not attractive enough even though we thought that it was attractive. We offered $475/week as stipend plus travel, lodging and food. One possible way of making the package better would have been cutting the number of REU students from 10 to 8 and increasing the stipend amount to $600/week or more. However, we wanted to provide research experience to more students. Thus, cutting the number of students to 8 was not a favorable choice. Other possible reasons for receiving only few applications from outside Michigan could be because of

the fact that this was our first year of a 3-year program, and we could not start advertising until our award was made by NSF. So we did not have enough time to collect applications. Another reason could be that the link of our REU homepage was not added to the NSF's list of REU sites until several months after the award was made.

We selected 10 applicants based on our selection criteria which required *3.0 GPA out of 4.0*, an *essay written by the applicant*, *two reference letters*, *courses taken by the applicant*, *be available for research work from 9:00am to 5:00pm*, and of course the applicant had to be either a *citizen or permanent resident* of the US. We received applications from five African American students and two of them were female. We made offers to both female African American students. One of them accepted our offer and the other one could not accept our offer due to a last minute personal problem. We also made offers to two male African American students. However, those two African American students could not accept our offers because they didn't want to give up their full-time summer job that they were working on. The remaining one African American applicant didn't take sufficient number of background courses to be able to actively participate in our REU program. The demographics of the selected students are shown in Table II.

Table II: Demographics of our Selected REU Students (Interns)

Gender

Female	3
Male	7

Location

New York	1
Puerto Rico	1
Michigan	8

Ethnicity

Asian	2
African American	1
Hispanic	1
White	6

Academic Standing

Sophomore	1
Junior	3
Senior	6

Institution

Our	4
Other	6

As shown in Table II, 30% of our interns were female, and 40% of the interns were Asian, African American or Hispanic. We selected 40% interns from our own institution and 60% from other institutions. However, 80% of the interns were from the State of Michigan.

Pre-Program Activities: These activities are also a part of the very important activities of an REU program. Well planned pre-program activities will avoid any last minute pitfalls with respect to arrival of students on campus, checking into university housing, getting parking tags, getting ID cards, getting meal plans, getting some cash advance, getting accounts for accessing university computer systems and internet access. Pre-program activities also include collection of students' personal information, emergency contact information, medical insurance information, collection of signed authorization forms for using survey data and their pictures for program dissemination and advertisement purposes, and distribution of campus maps with detailed information about how to arrive on campus and how to get into university housing. The start of the REU program activities could be severely disrupted if pre-program activities are not done timely and appropriately.

***Airport Transportation**:* Since 80% of the interns were from Michigan they used their own vehicles to drive to our campus. All students who wanted to stay in the housing of our institution arrived on Sunday evening. The intern from New York also drove. We had to pick up only one intern from the airport who came from Puerto Rico.

***Orientation**:* All students were required to attend Monday morning orientation. The orientation started with registration followed by introductions of REU interns, Program Directors, Department Chair, Dean of Engineering, and faculty and graduate student mentors. The introductions were followed by presentations by the Program Directors. The presentation slides included various information such as Program Overview, Program Objectives, Program Schedule, Program Formats and Program Requirements. The interns were clearly told what we expected from them during the program.

***Pairing of Students with Faculty and Graduate Student Mentors**:* As a part of the pre-program activities, the students were asked to visit faculty mentors' websites to become familiar with their research areas. The students were asked to provide us with the names of three faculty mentors, in rank order, with whom they would like to work. We did our initial pairing based on the students' choice. Final pairing was done at the orientation meeting when the students and faculty mentors had the opportunity to talk to each other. At the orientation meeting, research projects were also assigned to the students.

Graduate student mentors play a vital role for the success of an REU program. During summer time, most faculty members travel to attend professional meetings and present papers at conferences. At the same time, they are also busy in writing proposals and complete their unfinished work which they could not finish during the academic year due to lack of time. Thus, pairing the REU students with graduate student mentors is very important for the REU students to gain significant research experience in a short period of time. Our REU students worked under the supervision of their graduate student mentors on a daily basis. From time to time the students also met with their faculty mentors to seek advice from them and inform them about the progress of their work.

***Weekly Group Meetings**:* The REU students were required to attend our weekly group meetings. The meetings were also attended by the program directors, faculty and graduate students mentors, and graduate student coordinator. At the beginning of the meetings, each student verbally reported their weekly activities along with any issues or any special needs that appeared since the last weekly meeting. After that, two assigned REU students for that particular week, made technical presentations based on their research topic. In addition to students' technical presentation, the program directors and guest speakers also made presentations from time to time. Program directors' presentations were related to what research is, what is expected as research outcomes, how to write technical papers, how to make technical presentations, how to apply for graduate schools and what's needed to know for applying for graduate schools.

***Training to Develop Technical Communication Skills**:* Development of technical communication skills involves with writing technical reports, making technical presentations and preparing technical posters for poster session. At the beginning of the program, every REU

student was assigned reading materials, by his/her faculty mentor, related to the research project. The student spent significant amount of time on the reading assignment to become familiar with the research topic. The students were also required to make Power Point presentations, during the weekly group meetings, based on the reading materials and their research projects. The program directors made presentations, at the weekly group meeting, to provide detailed information about writing technical papers and preparing technical presentations and technical posters.

Training in writing technical papers started with the format of a technical paper such as *Abstract, Introduction, Background Material*, etc. Then detailed information was given about what to write in what section of the paper. Training in preparing and making technical presentations included with how to prepare presentations for different groups of audience, how to divide the presentation into different types of slides, how to select font color and font size, how to create slides with minimum text and more figures and charts. With respect to making technical presentations, the students were advised not to read slides, move around while talking, have body motions and maintain eye contact with the audience. Training on preparing technical posters was provided in a similar manner.

Field Trips*:* Educational field trips are also very important in gaining knowledge, infusing new ideas and enhancing research skills. During our REU program, we organized two field trips. After each field trip, the students were required to write a report. In the report, the students explained what they learned from the field trip; what part of the field trip was very exciting for them; and whether the field trip met their expectations and in what way. The students were asked to rate each field trip using a scale of 1 through 10, with 1 being the worst and 10 being the best. The students were also asked whether they would recommend the field trip for the next year's REU program.

During the first trip, the students had the opportunity to visit robotic assembly line of automobile industry. The field trip had six attractions: *Legacy Theatre, Art of Manufacturing Theatre, Observation Deck, Assembly Plant, Legacy Gallery,* and *Living Laboratory Tour.* The students visited all six attractions and indicated in their report that they liked all the attractions of the field trip. The average rating for this field trip was 7.8 in a scale of 1 through 10 which means that it was an effective trip for the students. Out of our 10 REU students one student was from computer science with no engineering background. Only this student was not as happy as other students with this field trip. This student's rating for the field trip was 6. All students except this computer science student recommended this particular field trip for next year's REU program. All the students who recommended this field trip for the next year's REU program also indicated in their report that they learned a lot from this field trip.

During the second field trip, the students visited Henry Ford Museum and Greenfield Village. Henry Ford Museum hosts many objects from America's past such as automobiles, trains, power, agriculture, American liberties and also historically significant objects such as Kennedy's limousine and Rosa Park's bus. Greenfield Village is a collection of famous and iconic buildings from America's history such as Edison's workshop, Wright Brother's house, Edison's Menlo Park workshop and many others. The students also enjoyed this field trip and learned a lot as they mentioned in their reports for this field trip. The average score given to this field trip by the

students was 7.6. All students except the computer science student recommended this field trip for the next year's REU program.

***Students' Assignments**:* During the 8-week long summer REU program, in addition to the students' research assignments given to them by their faculty mentors, the students were required to write two field trip reports, a mid-term report, and the final report. The students were also required to make one Power Point technical presentation and prepare a technical poster for the poster competition. These intensive research and technical communication skill development activities enabled the students to significantly improve their technical communication skills during a short period of time.

***Students' Research Projects**:* The students' research projects were in the areas of wireless communications for vehicular applications, fashion computing, multimedia, cloud computing, document validation etc. A complete list of the projects long with the abstract of each project is shown below:

a. *Digital Document Authentication*

Abstract: The goal of this research work is to illustrate a new method of certifying and authenticating digital documents. This method aims to exploit the distinctive characteristic of a paper document's grain structure to develop a unique paper signature to certify the document's authenticity. The grain structure of one sample of paper, will never have quite the same characteristics of another sample paper, even if both samples are of the same color, type, or originated from the same source. The documents are compared digitally, requiring the authenticator to have a digital image of the paper document in question as well as a digital image of the original document. The intent of this method is to apply a "fingerprint" signature to each certifying document in order to safeguard against counterfeiting. This certification method is highly invulnerable to the main forms of counterfeiting, copying and spoofing, as replicating or reconstructing a paper's grain structure becomes quite difficult.

b. *Fashion Computing*

Abstract: Construction kits have a long history in encouraging and enhancing creativity with engineering and design amongst children, novices and professionals. In response to the growing research of integrating human interaction with computers, electronic textiles construction kits have been formed to introduce and engage interest in electrical engineering and computer science. The LilyPad Arduino construction kit, the latest construction kit within the electronic textile prototype family, allows users to create their own wearable computer designs. The goal of this project was to learn techniques behind fashion computing and apply the techniques towards new design. Because the LilyPad electronic textiles kit is already commercially available is work became a service learning experience. However, this work could be studied by elementary and middle school students to enhance their interest in computing.

c. *Increase Performance with Remote Procedure Calls*

Abstract: Mobile devices are increasing in popularity, but are limited by weak hardware. We propose and examine using remote procedure calls to export tasks from mobile devices to more powerful, remote systems in an attempt to increase application performance and potential. An implementation of checkers is created to compare the use of classical and remote procedure call techniques. The results shows that, no matter what the configuration is, the test ran at least 2 times faster; reaching up to 8 times faster. This suggests that Remote Procedure Calls can in fact increase performance. Under the right conditions they may be able to increase performance even further.

d. *Network Simulators for VANET Broadcast Methods*

Abstract: Complex broadcast methods in VANETs (vehicular ad-hoc networks) require specialized simulation techniques to determine performance of various broadcast techniques. Previous methods like theoretical calculations or general simulations will not work. Network simulators like OPNET, NS2, and GloMoSim are able to handle the large amounts of nodes and traffic needed to test broadcast methods. Because they can configure nodes into groups, they can test how groups can help improve broadcast methods. This project was about the use of simulation techniques for VANET applications.

e. *Offloading CPU Intensive Applications to the Cloud Using Java RMI*

Abstract: The term "cloud computing" is becoming more and more popular in the mass media, but what does the term really mean and what are its implications? The current consensus of the definition of the "cloud" is the combination of hardware and software provided remotely as a service. This research focused on analyzing the potential of cloud computing. More specifically, purpose this research was to determine whether it is beneficial in terms of speed to offload CPU intensive applications to a powerful server in the cloud. While currently tests were run only using a desktop computer as the client, the ultimate goal is to offload applications from a mobile device. This research has shown that offloading a computationally intensive application to a remote server can be significantly faster than running the same application on a local machine. In fact, it can take 80% less time to run an application on the server compared to running it on the local client machine.

f. *Optical Signal Detection in Strong Turbulence*

Abstract: In this study the signal detector performance for an optical communications system employing a p-i-n photodiode and operating through the turbulent atmosphere is investigated. The effect of the turbulent atmosphere on the signal is modeled as a gamma-gamma random process which can be manipulated to fit weak to strong turbulence. The probability of miss is evaluated through Monte Carlo simulations. Using the probability of miss and the probability of false alarm, the appropriate signal length and detection threshold can be determined so that the required system performance is met.

g. *Performance Variations in Cloud Computing*

Abstract: Cloud computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services. Cloud computing, the long-held dream of computing as a utility, has the potential to transform a large part of the IT industry. It is a cost-effective, scalable solution to traditional computing. Amazon and Google have already created their own clouds, and many more companies are predicted to follow. This project dealt with the performance unpredictability of cloud computing by running benchmark tests and comparing their performance in the cloud. The first benchmark that was run was called IOzone, which focuses on I/O performance. The benchmark was run alone, and then simultaneously on two Virtual Machines. The results show that the simultaneous Virtual Machines always have different performance. The Rewrite and Backward Read tests showed the biggest performance difference. The next benchmark that was run was the NAS Parallel Benchmark (NPB). It is a collection of CPU-intensive tests designed to compare parallel computational performance. The percent difference in run time for the BT, LU, and SP tests were 25%, 35%, and 22% respectively. This difference is significant and needs to be addressed when usage charges are being calculated.

h. *Raman Spectral Analysis and Classification*

Abstract: Raman spectroscopy is a promising tool for cancer detection. However, there are drawbacks associated with sending the data to a lab to be analyzed, such as a long wait period for results. The Raman processing software application is being developed to make it easier to use automated preprocessing and data analysis methods on Raman spectra. In addition, the application will provide the ability to analyze Raman spectral peaks. These peak analysis methods output either what a particular peak may represent or various products that the spectrum as a whole may contain. Support vector machine classification will allow unknown data to be tested against a support vector machine that has been trained with two classes of known data thereby allowing the user to determine which type that it belongs. Our Raman processing project utilizes MATLAB to automate many processing techniques to remove noise, subtract intrinsic tissue fluorescence, and normalize the data. These techniques help to eliminate subjective interpretation of the data and reduce error. The peak analysis functions enable a quicker analysis of the peaks present in the spectrum and determine if any known chemicals are present. The support vector machine (SVM) classification allows for training a SVM with samples that the user knows about and using that to classify unknown samples into one of the two classes that were used. The overall goal of these techniques and the entire system is to produce a method that makes the analysis of Raman spectra easier, faster, and more accurate.

i. *Sonic Infrared Imaging (SIRI)*

Abstract: A simple process is necessary to detect defects in materials and structures in a short period of time to maximize its potential in the industry. With sonic infrared (SIR) imaging it is possible to identify defects, surface or subsurface, such as cracks, delaminations, disbonds

and others in less than sixty seconds. Sonic infrared imaging is a simple three step NDE technique, ultrasonic excitation, infrared imaging, and data/image analysis, used to simplify nondestructive evaluation. The process involves a short ultrasonic pulse which excites the material being tested and a sonic infrared video camera is used simultaneously to capture the temperature change caused by frictional heating by the excitation source. The data/image produced is then analyzed using a heating-time plot. The ultrasonic sonic pulse causes vibration and if there is a defect then rubbing or clapping of the faying surface causes frictional heating thus temperature change. Sonic infrared imaging can be used to improve product quality, increase safety, lower the cost of manufacturing and reduce scrap.

j. Using The YouTube API'S And Tools To Develop Application For Vehicles

Abstract: Multimedia is very important in our daily life. We have multimedia everywhere in computers, televisions and even on the fridge and the oven. But since a couple of years ago multimedia which is used in contrast to media which only use traditional forms of printed or hand-produced material. Multimedia includes a combination of text, audio, still images, animation, video, and interactivity content forms have being implemented on cars for several different reasons. These reasons mainly include safety, entertainment, communication and the all popular Global Positioning Systems (GPS). The main focus of this project is to create a user friendly interface to let the user, in this case the driver or the passengers of the car, connect to an online video service in this case YouTube using the YouTube API'S and Tools. This application may lead us to others application such medical, safety and communication applications among many others. Using the YouTube Data API we were able to do some applications for future use. One of these applications is an Authentication script to be able to connect to the YouTube server using Ruby Scripting Language. And also following some tutorials online we were able to get links from YouTube, using PHP and Ruby.

Management Activities: To successfully run an REU program, significant amount of time is required from the people who will be managing the activities. The management activities include dealing with various issues such as housing, meal plan, establishing computer accounts, payroll, field trips, transportation for field trips and dealing with day to day issues that may arise during the program. It's important that day to day issues are taken care of immediately. Otherwise, students' research activities could be significantly jeopardized given that the length of the program is only 8 weeks. We had two people responsible for all the management activities. One of them is the administrative secretary of our department and the other one was a graduate student.

Evaluation: Program evaluation is a very important component to monitor and continuously improve the program activities. We did the formative evaluation using both *direct* and *indirect* methods. The direct method of evaluation involved assessing the students' work in writing technical reports and making technical presentations. For the indirect method of evaluation, we conducted three surveys: pre-program survey, mid-program survey and exit survey. The pre-program survey was conducted during the orientation; the mid-program survey was conducted at the end of the fourth week of the program; and the exit-survey was conducted on the last day of the program.

Direct Evaluation: Altogether the students wrote four reports, made one technical Power Point presentation and prepared on technical poster. The program directors read the technical reports written by the students, and then provided the students with feedbacks and suggestions for improvement. The program directors also made presentations, during weekly meetings, to explain how better reports could be written and what needs to be included in a good technical report. The students' technical presentations were judged based on: i) organization of the presentation, ii) technical contents of the slides, iii) problem statement of the presentation, iv) background materials covered in the slides, v) selection of figures, charts and amount of texts in the slides, vi) visual quality of the slides, vii) whether the student was reading slides or talking, viii) whether the student maintained eye contacts with the audience, ix) whether the student moved around while talking or stayed at one place like a statue, x) whether the conclusion slide was made objectively and many other factors. At the end of the presentation, the students were also provided with feedback regarding how they did in their presentations and how they can further improve their presentation skills. The poster presentation was evaluated based on: i) poster contents, ii) organization of poster contents, iii) poster writing style, iv) clarity of the poster and v) how well the discussion and conclusion sections were written.

Indirect Evaluation: Indirect evaluation was done using three surveys: pre-program survey, mid-program survey and exit-survey.

a) Pre-Program Survey: The pre-program survey questionnaire was prepared to determine the effectiveness of the advertizing techniques of our REU program and the background of our REU students. The pre-program survey was administered during the orientation meeting. The results of the survey are shown in Table III.

Table III: Results of Pre-Program Survey

Question	**Answer**
1. How did you hear about the REU program?	Flyer = 2 REU Homepage = 3 Friend = 1 My Own School = 5
2. How effective are the methods used to advertise the REU program?	Very Effective = 0 Effective = 9 Not Effective = 1
3. How convenient is the application process?	Very Convenient = 5 Convenient = 5 Not Convenient = 0
4. Did you find necessary information from the REU homepage?	Yes = 10 No = 0
5. Do you want to see any additional information on the REU homepage?	Yes = 4 No = 6
6. Was it easier for you to select faculty mentors based on the information available on their websites?	Yes = 10 No = 0
7. Do you have any prior research experience?	Yes = 4 No = 6
8. Have you taken any courses on how to write technical papers and make technical presentations?	Yes = 6 No = 4
9. Have you taken any courses on ethics?	Yes = 6 No = 4

Table III: Results of Pre-Program Survey (continued)

Question	Answer
10. Have you made any technical presentations outside your classroom?	Yes = 5 No = 5
11. Have you written any technical papers for activities other than your course work?	Yes = 2 No = 8
12. Did you apply for any other REU programs?	Yes = 3 No = 7
13. Did you receive offer from any other REU programs?	Yes = 2 No = 1 N/A = 7
14. If you applied for other REU programs, how are our stipend and benefits compared to those of other programs?	Better = 0 Same = 2 Not As Good = 1 N/A = 7
15. Do you plan to go to graduate school either immediately after completing your undergraduate degree or after few years?	Yes = 9 No = 0 Not Sure = 1

From the pre-program survey results it is seen that our advertisement technique was effective; the application process is very convenient and all the students were able to find necessary information on our website; it was very easy for the students to select faculty mentors based on the information available on our website; and nine out of ten students definitely will go to graduate schools after completing their undergraduate education. Some students wanted to see additional information on our REU homepage. Some comments under Question 5 were: i) information about specific projects that the relevant faculty members are working on would be helpful, and ii) little more information about housing and availability of food would be helpful. Based on the comments we received, we are putting more information on our homepage. As far as the background of the students is concerned, some students had some prior experience in research and technical communication. Nine out of ten students plan to go to graduate school after their undergraduate study. Thus, we were lucky to get a pool of motivated students.

b) Mid-Program Survey: The mid-program survey was done at the end of the 4th week of the program to determine how the program has been running so far. The survey was also done with the intention of getting feedback from the REU students so that the program could be improved during the second half of the program duration. The results of the mid-program survey are shown in Table IV.

The survey results show that the program has been running well so far during the first half of the program with some exceptions or glitches. One REU student indicated that his graduate student mentor was not available as he expected. However, the REU student wrote in his comments that his graduate student mentor used to return his calls at the end of the day. Seven out of ten students indicated that the reading materials were difficult. It was expected because the reading materials were journal and conference proceedings papers and undergraduate students are not exposed to research articles from their class room activities. Moreover, six of them did not have any prior research experience and the other four had limited prior research experience. One or

two students indicated that they were still not sure what needs to be included in technical presentations and technical reports. Some of these glitches occurred due to the fact that this was our first year of a 3-year program, and during the first year everything needs to be developed and organized from the scratch. After the mid-program survey, the program directors made presentations in weekly meeting to explain in detail about how to write a technical paper and prepare a technical presentation. So far until the middle of the program, 9 students were very satisfied or satisfied with the program. Only one student was somewhat satisfied. This is the computer science student who had some dissatisfaction with the field trips as the field trips were mostly on engineering topics and the student had no prior background in engineering or engineering applications. Since 90% of the students were satisfied until the middle of the program, we believe that the program was running as expected. During the mid-program survey the students wrote the comments: 1) Possibly provide the student with a list of possible projects to have a better idea. Have more of an outline/timeline for the projects; 2) At the beginning of the program the students are to be clearly told about weekly expectations from them; 3) Discuss requirements for presentations and papers sooner so that all interns are clear about their responsibilities; 4) More presentation practices are needed and better selection of field trips is necessary for non-engineering students.

Table IV: Results of Mid-Program Survey

Question	**Answer**
1. Did you get enough information from the orientation meeting on the first day of the program?	Yes = 10 No = 0
2. Has the graduate student mentor been available to you whenever you wanted to meet him/her?	Yes = 9 No = 1
3. Have you been assigned any reading materials or any other tasks by your graduate student mentor or faculty mentor?	Yes = 10 No = 0
4. If you have been assigned reading materials, how difficult was it for you to understand the materials?	Very Difficult = 0 Difficult = 7 Not Difficult = 3
5. Do you understand what needs to be included in a technical presentation?	Definitely Yes = 2 Yes = 6 No = 2 Definitely No = 0
6. Do you understand how to write a technical paper?	Definitely Yes = 1 Yes = 8 No = 1 Definitely No = 0
7. Are field trips useful to enhance your knowledge?	Definitely Yes = 3 Yes = 7 No = 0 Definitely No = 0
8. Do you believe that so far the REU program has been helpful for you to gain research experience?	Definitely Yes = 6 Yes = 4 No = 0 Definitely No = 0
9. So far how satisfied are you with the REU program?	Very satisfied = 4 Satisfied = 5 Somewhat satisfied = 1 Not satisfied at all = 0

c) Exit Survey: The exit survey was done on the last day of the program to determine how successfully we ran our REU program. The results of the exit survey are shown in Table V.

Table V: Results of Exit Survey

Question	Answer
1. Do you understand what needs to be included in a technical presentation?	Definitely Yes = 3 Yes = 7 No = 0 Definitely No = 0
2. Do you understand how to write a technical paper?	Definitely Yes = 4 Yes = 6 No = 0 Definitely No = 0
3. Do you understand how to prepare a technical poster?	Definitely Yes = 3 Yes = 7 No = 0 Definitely No = 0
4. Are field trips useful to enhance your knowledge?	Definitely Yes = 2 Yes = 7 No = 1 Definitely No = 0
5. Do you believe that so far the REU program has been helpful for you to gain research experience?	Definitely Yes = 5 Yes = 5 No = 0 Definitely No = 0
6. How helpful were your program manager and program coordinator?	Very helpful = 6 Helpful = 3 Little helpful = 1 Not helpful at all = 0
7. During the program, did you receive sufficient help to resolve whatever issues you had?	Definitely Yes = 3 Yes = 5 No = 2 Definitely No = 0
8. So far how satisfied are you with the REU program?	Very satisfied = 5 Satisfied = 3 Somewhat satisfied = 2 Not satisfied at all = 0

From the exit survey it is seen that by the end of the program all REU students knew how to write technical papers, how to prepare technical presentations and technical posters. We had field trip issue with one student who is the computer science student. Regarding the administrative part of the program, Question 6, nine students said that the program manager and program coordinator were very helpful or helpful, and only one student said they were little helpful. Questions 7 and 8 received positive feedback from 8 students, and slightly negative review from the other two students.

Poster Competition: On the last day of our 2009 program, we organized a poster competition session along with a concluding lunch session. We invited all graduate student mentors, faculty mentors, chair of the department and dean of engineering to attend both lunch and poster sessions. All posters were evaluated by all graduate student and faculty mentors. An award was given to the student who prepared the best poster. In addition, during the lunch session, each student was given a certificate indicating that he/she successfully completed our REU program.

Post Program Monitoring: To determine the effectiveness our REU program and how it is affecting the students who already completed the program, it is important to monitor the progress of those students at least for another couple of years. We will do a post-program survey one year after they completed our program and another post-program survey two years after their completion of our program. Just before writing this paper, we sent emails to last year's REU students to determine their status about five and a half months after completion of the program.

One student started graduate school beginning from Fall-2009 semester, and two other students are starting graduate schools beginning from this Winter-2010 semester. Another student said that he will graduate by the end of Winter-2010 semester and start graduate school from Fall-2010. Five students are still working towards their undergraduate degree, and we have not heard from one student yet. Thirty percent of our last year's students are already in graduate schools which is definitely a good sign.

Improved Student Learning

The main focus of our REU program was to enhance student learning in a number of key areas such as, understanding technical papers, performing experiments, developing codes for collecting data, analyzing data, understanding research problems, developing research skills, writing technical papers and making technical presentations.

Most students of our REU program did not have any prior research experience before joining our program though some of them had some background in performing experiments and developing codes for some class projects. During the 8-week long program, we helped students to understand what research is, how to do research and how to report and present research results. During the first two to three weeks, the students needed lots of help from their graduate student and faculty mentors. But during the remaining period of the program, they were able to work independently and did not require as much help from their mentors as they required during the first few weeks. This indicates that they significantly improved their research skill compared to what they had prior to joining our program. The students wrote two technical reports and two field trip reports during the program. After each report, feedback was provided to the students. Their report writing skill gradually improved from one report to the next report. Detailed instructions were given to the students regarding how to prepare technical presentations and what needs to be included in presentation slides. Their power point technical presentations and poster presentations were judged by graduate student and faculty mentors. Assessments of their presentations and poster session were found to be very good. Thus, it indicates that the students significantly improved their research as well as technical communication skills.

Improvements for the 2010 REU Program Based on the Feedbacks Received from the 2009 Program

We have modified the contents of our REU homepage based on the feedbacks received from the last year's program. The new items that we added to our website are 1) information about housing and meal plan, 2) information about airport transportation, 3) list of last year's projects with an abstract for each project, 4) list of new projects for the 2010 REU program with short descriptions for each project, 5) students' responsibilities with weekly outcome expectations, 6) weekly outcome expectations will be clearly mentioned at the orientation of the 2010 program.

Training on how to write technical papers, and prepare and make technical presentations will be started from the first week of the program. In 2009, we didn't start this training until the 3rd week

of the program. We will advise our management team to take care of the students' need immediately. We will solicit inputs from the students regarding choice of field trips.

Recommendations for Other People Who Want to Start an REU Program

Here we provide some recommendations based on the lessons that we have learned from our 2009 REU program. For additional recommendations, the readers are referred to the paper written by Miguel A. Labrador and Rafael Pérez [15].

Table VI: Recommendations for a Successful REU Program

Item	Required Actions
1. Planning	The key to the success of an REU program is advance planning and organization. So start early and be ready even before your award is made because once you know that your award is made, at that time it's too late to advertise.
2. Homepage	A well designed and well organized homepage is a must, because students will expect to find all necessary information about your program from your homepage. On your homepage, try to keep a list of projects with a description of each project. On your homepage, also keep information about faculty mentors, contact information of management team and program directors, contact information of public safety, housing, meal plan, airport transportation, schedule of your program, daily working hours, students' responsibility and expectations from the students.
3. Advertisement	Advertise your homepage on the NSF's list of REU sites immediately after your award is made.
4. Management Team	Communicate with your management team and advise them to take care of students' need as soon as possible.
5. Housing and Other Items	Make arrangements for housing, meal plan, ID cards, computer and internet accounts before the students arrive on campus.
6. Authorization Forms	Get signed authorization forms from the students before they arrive on campus or at the orientation meeting so that you will be able to use their pictures and activities for program disseminations and advertisements.
7. Training for Technical Communication Skills	Provide training in developing technical communication skills early in the program.

Table VI: Recommendations for a Successful REU Program (contd.)

Item	Required Actions
8. Graduate Student Mentors	If possible, select your graduate student mentors before the students start the program. Advise graduate student mentors regarding their role in the program and how critical it is for them to mentor the REU students.
9. Field Trips	Select field trips appropriately so that all REU students can enjoy and learn from the trips.
10. Chargeable Expenses	Before you organize field trips or lunch seminars with guest speakers, check with the business office of your college or university to find out whether the related costs could be charged to your grant account. Don't assume anything for guaranteed.

Conclusions

Research Experiences for Undergraduates (REU) programs are very effective in infusing research ideas to the undergraduate students. It's also an effective vehicle for addressing several important problems in engineering education. It can also provide research experience to those students who are from non-research institutions. It can increase the number of female and minority population in STEM careers by involving them in the REU programs. To be successful in running REU programs, these programs must be designed and implemented carefully so that they achieve their objectives. This paper presents our experience in running our own REU program. The key lesson that we have learned from our program is that advance planning and organization is a must. An active management team is also necessary to meet day-to-day needs of the students. All activities of the program must be carefully designed, implemented, managed, monitored and evaluated. Both graduate student and faculty mentors must be actively involved for the students to be happy and gain expected research experience.

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Bibliography

1. Tinto, V., Goodsell, A., Love, A., and Russo, P., Leaving College: Rethinking the Causes and Curses of Student Attrition, The University of Chicago Press, 1993.
2. Peter J. Shull and Michael D. Weiner, Thinking Inside of the Box: Retention of Women in Engineering. 30th ASEE/IEEE Frontiers in Education Conference. 2000. Describes efforts at Penn State to increase retention of women.
3. Carnegie Foundation's Boyer Commission. Reinventing undergraduate education: A blueprint for America's research universities. 1998.
4. Mogk, D.W. "Undergraduate Research Experiences as Preparation for Graduate Study in Geology," Journal of Geology Education, Vol. 41, pp. 126–128, 1993.
5. Tomovic, M.M. "Undergraduate Research—Prerequisite for Successful Lifelong Learning," Proceedings of the 1994 ASEE Annual Conference, Vol. 1, pp. 1469–1470, 1994.
6. Lopatto, D. "The Essential Features of Undergraduate Research," Council on Undergraduate Research Quarterly, Vol. 24, pp.139–142, 2003.
7. Fitzsimmons, S.J., Carlson, K., Kerpelman, L.C., and Stoner, D. A Preliminary Evaluation of the Research Experiences for Undergraduates (REU) Program of the National Science Foundation. Washington, D.C.: National Science Foundation, 1990.
8. Zydney, A.L., Bennett, J.S., Shahid, A., and Bauer, K.W. "Impact of Undergraduate Research Experience in Engineering," Journal of Engineering Education, Vol. 91, pp.151–157, 2002.
9. Nagda, B.A., Gregerman, S.R., Jonides, J., von Hippel, W., and Lerner, J.S. "Undergraduate Student-Faculty Partnerships Affect Student Retention," Journal of Review of Higher Education, Vol. 22, pp. 55–72, 1998.
10. Hathaway, R.S., Nagda, B.A., and Gregerman, S.R. "The Relationship of Undergraduate Research Participation to Graduate and Professional Education Pursuit: an Empirical Study," Journal of College Student Development, Vol. 43, pp. 614–631, 2002.
11. Kremer, J.F., and Bringle, R.G. "The Effects of an Intensive Research Experience on the Careers of Talented Undergraduates," Journal of Research and Development in Education, Vol. 24, pp. 1–5, 1990.
12. Bauer, K.W., and Bennett, J.S. "Alumni Perceptions Used to Assess Undergraduate Research Experience," Journal Higher Education, Vol. 74, pp. 210–230, 2003.
13. Seymour, E., Hunter, A.-B., Laursen, S., and DeAntoni, T. "Establishing the Benefits of Research Experiences for Undergraduates: First Findings from a Three-Year Study," Science Education, Vol. 88, pp. 493–594, 2004.
14. National Science Foundation REU Sites, (http://www.nsf.gov/crssprgm/reu/reu_search.cfm).
15. Labrador , M. A., and Rafael Pérez, R. "Fulfilling Mentors' Expectations: An REU Site Experience", 2006 ASEE Southeast Section Conference, 2006.