# AC 2008-2667: SUMMER AND ACADEMIC YEAR UNDERGRADUATE RESEARCH IN NUCLEAR ENGINEERING

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# Summer and Academic Year Undergraduate Research in Nuclear Engineering


## Abstract

Undergraduate research participation has become important in engineering and more so in Nuclear Engineering. There is a strong interest among faculty to seek interested undergraduate student participation in their research projects. The undergraduate research has often been used as a recruitment tool for graduate schools. The undergraduate research participation in general has benefitted both students and the faculty and has given rich experience to the graduate students and researchers who otherwise would not interact with undergraduate students. The Nuclear Engineering student groups are generally small and this interaction has more impact on student learning. The undergraduate research during summer and during academic year in nuclear engineering program is reviewed. Key lessons learnt by faculty and graduate students and feedback by undergraduate students are summarized in this paper.


## Introduction

The Boyer Commission Report[1] recognized that the majority US research universities had failed to integrate the research with undergraduate education even though the research successes were used in recruiting undergraduate admission. The report recommended a new model for undergraduate education at research universities where research based learning will be an inseparable part of baccalaureate experience. The model involved undergraduate research experience with senior researchers, faculty and their graduate students. A 1998 workshop at National Research Council[2] stated that "research is a necessary component of the bachelor's degree education." Recently there is dramatic increase in the number of institute wide undergraduate research programs in science and engineering. The first institution-wide undergraduate research program at a major research university was developed at the Massachusetts Institute of Technology in 1969 and has been followed by a number of other research universities. The National Science Foundation has presented undergraduate research as a critical component of its core strategy for education reform. The National Science Foundation began providing financial support for such efforts in 1987 through the Research Experiences for Undergraduates program, which was specifically designed to attract talented students into research careers in science and engineering. Some programs now require undergraduate research as part of the B.S. degree to meet the Accreditation Board for Engineering and Technology (ABET) engineering criteria.

There are several benefits in the undergraduate research participation. Faculty mentors generally agree that significant educational benefits result from the undergraduate research experience. Students develop expertise in an area of specialization, gain a better understanding and appreciation of the research process, and acquire skills in team work, communication, problem-solving, and critical thinking. A recent University of Delaware study[3] indicated that undergraduate research experience was "very" or "extremely" important to their overall education. The benefits to undergraduates include that they are more likely to pursue graduate degrees, greater enhancement of their ability to carry out research, speak effectively, understand

scientific findings, know literature of merit in the field, analyze literature critically, and possess clear career goals. It should also be noted that there are other issues with the undergraduate research. There is considerable pressure on universities to offer undergraduate research programs to more effectively recruit the best high-school seniors[4]. Undergraduate research programs can be very expensive, including the significant demands on faculty time and effort.

Currently there is renaissance in nuclear industry with new arrival of reactor designs and the industry looking to build new reactors. In response to this the undergraduate enrollments in nuclear engineering programs have almost doubled in last few years. The nuclear engineering programs in US are generally small in size compared to other engineering. The small size of student body enables stronger interaction between the undergraduates and the faculty. This gives undergraduate students greater opportunity to participate in the faculty research. In fact nuclear engineering faculty recognizes this as an opportunity to encourage the undergraduates to continue for graduate studies.

**Undergraduate Research at Purdue University**

Purdue University has several undergraduate research programs that are multi-subject, single disciplinary and interdisciplinary. The multidisciplinary undergraduate research programs include the followings. (1) Center for Authentic Science Practice in Education (CASPiE) :Multi-institutional collaborative effort designed to increase and improve classroom research experiences for younger undergraduate science students. (2) Committee on Institutional Cooperation (CIC) Summer Research Opportunities Program: Research one-on-one with faculty mentors (3) Discovery Park Undergraduate Research Internship Program (DURIP) which gives research opportunities during fall and spring semester. (4) MARC/AIM Summer Research Program: Encourage Students Underrepresented social and economic backgrounds. (5) Summer Bridge Program: This bridge program is for all qualified students, including but not limited to, underrepresented multicultural students on a path toward success in Purdue's graduate programs. (6) Summer Undergraduate Research Interns (SURI).

The College of Engineering has the following programs in undergraduate research. (1) Biomedical Engineering Research Experience for Undergraduates: Non-Purdue students who have completed 4 semesters of undergraduate work. (2) Civil Engineering Research Internship: 10-week Joint Transportation Research Program. (3) Introduction to Engineering Opportunities through Research in Materials Processing: This program welcomes students in science and engineering who have little or no background in materials engineering. (4) Summer Undergraduate Research Fellowships Program (SURF): A campus-wide program for undergraduate students in engineering, science, and technology disciplines. The Life Sciences, Agriculture, and Medicine Programs in undergraduate research include: (1) Agriculture Summer Research Program – Ag-SRP, (2) Botany and Plant Pathology Summer Research Program, (3) Entomology Undergraduate Research Opportunities and (4)Pharmacy and Pharmaceutical Sciences Dean's Summer Undergraduate Research Fellowship Program . In the Science, Mathematics, Computer, and Technology the undergraduate research Programs are (2) Chemical Biology Research Experience for Undergraduates, and (2) Computer Sciences Research Opportunities.

**Summer Undergraduate Research Fellowships (SURF)**

The SURF program was initiated in 2003 using a portion of an unrestricted gift from Purdue University Alum. Purdue's College of Engineering launched the program to meet the increasing needs of academia and industry by providing a dedicated laboratory experience to strengthen integrated, research-related, hands-on learning through discovery for participating students. The goal of the SURF program is to provide students across *all* engineering, science and technology disciplines with an *intensive research* component that allows them to work closely with *graduate students and professors* in their respective schools.

The Purdue SURF Program has the following features: (1) Paid, hands-on research under the guidance of a faculty member and a graduate student, (2) Weekly seminars on research methodology, graduate school, and professional development, (3) Student poster presentations, (4) Social activities for networking with faculty, staff, and other SURF students and (5) End of summer banquet. The students are paid a total of $3000 for the summer with one third of the budget contributed each by the college, department and the faculty. The SURF program is open to Purdue students and undergraduate students enrolled in other USA colleges and universities and as well as for undergraduates from abroad. There is also summer Research Abroad program for Purdue students launched in 2006 subject to faculty and student interest as well as availability of international laboratory hosts. Now the for Purdue students there is Year Round Research which provides research opportunity for Engineering and Science undergraduate students to work during the Spring semester and the summer session in research laboratories at Purdue University.

**Research Projects**

For the past 7 years, 34 undergraduate students have participated in research activity in Multiphase and Fuel Cell Research Laboratory (MFCRL) of the School of Nuclear Engineering. The research projects and the period of the performance of the research are shown in Table 1. The topics of the project vary, ranging from energy storage to code modeling. The research topics are assigned to the undergraduate students based on their interest and background. Students from various disciplines have participated in the research including nuclear engineering, mechanical engineering, chemical engineering, physics, and chemistry. 10% of the student participated are minority students and 3% are from other institute.

Table 1. Undergraduate Research Projects In Multiphase and Fuel Cell Research Laboratory

| Project | Period Performed |
|---|---|
| | |
| Void Distribution In Spherical And Torus Capsules With Phase Change Material | 2001,Summer |
| RELAP5 Modeling Of PCCS | 2001 Fall -2002 Spring |
| Effect Of Non-Condensable Gas In A Vertical Tube Condenser | 2001-2002 Fall, Spring |
| Study Of Void Formation And Distribution In Phase Change Material And Its Impact On Energy Storage Systems | 2001-2002 Summer Spring and |

| | Fall |
|---|---|
| Multiphase Flow Loop Design | 2002-2004 Summer Spring and Fall |
| Bipolar Plate Design For Fuel Cell | 2003-2004 Summer Spring and Fall |
| Hydrophobic And Hydrophilic Electrode Catalyst For Fuel Cell | 2003-2004 Summer Spring and Fall |
| PEM Fuel Cell Testing | 2005-Spring |
| Sodium Borohydride Fuel Cell Development | 2005-Spring and Summer |
| Packed Bed Two-Phase Flow | 2005 Summer |
| Fuel Cell for High Altitude Airship Modeling | 2005 Summer |
| FEMLAB Model for Sodium Borohydride Fuel Cell | 2005 Summer |
| Catalyst development for Sodium Borohydride Fuel Cell | 2006 Summer |
| Testing of Sodium Borohydride Fuel Cell | 2006 -2007 (Fall Spring, Summer |
| Design and Building of Multitude Passive Condenser Loop | 2006 Summer, Fall 2007 Spring, Summer |
| Modeling Pressure Drop and Liquid Holdup in Packed Bed | 2006 Summer |
| Analysis of Pressure Drop and Liquid Holdup in Packed Bed | 2006 Summer, Fall |
| Multitude Condenser System | 2006 Fall, 2007 Spring |
| SOFC based Regenerative System for Closed Environment | 2006 Fall |
| Molten carbonate Fuel Cell Modeling | 2007 Spring |
| Sodium Borhydride Fuel cell | 2007 Spring |
| Fuel Cell System Design For Strategic Power Supply | 2006 Fall, 2007 Spring |
| Thermochemical Modeling of SI Cycle | 2007 Spring |
| Regenerative Fuel Cell for Closed Environment | 2006 Fall, 2007 Spring |
| Sodium borohydride hydrolysis Experiments | Summer 2007 |
| Sodium borohydride hydrolysis and Analysis | Summer 2007 |
| Steam generator tube integrity | Fall 2007 |
| CANTIA Code for assessment of steam generator tube integrity | Fall 2007 |
| PCCS condensation heat trsnfer | Fall 2007 |
| Molten carbonate fuel cell model for hybrid system | Fall 2007 |
| Solid oxide fuel cell regenerative system | Fall 2007 |

**Project Preparation and Progress**

Though student have expressed interest in particular area when they applied for the research program it was often the case that the actual project specific were assigned after the first week of the students participation. During the first the students are asked to provide details of their background pertinent to the project subject. This determines the initial reading and preparatory

work required by the student to conduct the project. Each undergrad student is assigned with a graduate mentor who is either senior MS or PhD student. Student working with a computer code or in the laboratory undergoes training during the first week. The training depends on the type of the project. If it is experimental project then for the first week training is provided on the team work, laboratory hazard and safety, and laboratory methods. Students are authorized to work on the experiment only after they have fully understood the laboratory safety and emergency procedures. The students get a computer account supported by college wide network for their use during the summer period.

Each student is given with a laboratory notebook which is used to enter work done on daily basis. The note book is checked every week by the faculty to monitor the progress and to provide advice to the student. The feedback from the graduate mentor is used in verifying the activity. The undergraduate students attend weekly research meeting which is held with all graduate students and post-doctoral researchers in the team. This gives an opportunity for students to hear about other research work conducted in the group and also to listen to the discussion and reports on those projects. The students are encouraged to participate in the discussion about other research work during the meeting. The undergraduate students have to make two presentations to the group about the work in progress. This helps the students to communicate about their project to others. Students also attend weekly two hour seminar by the SURF administrator.

The students prepare a final report at the end of the work period. This report format is similar to the scientific journal manuscript. A poster describing the research work is prepared by the student and is presented at the open house arranged by the SURF office. Student has opportunity to explain the audience about their research work during the poster sessions. After conclusion of the summer research work each student gives a feed back report to the supervising faculty and the SURF office.

**Outgoing Survey Results**

The survey of all outgoing SURF students' feedback reports was made and analyzed. The following observations were made from this survey.

Students work between 25 to 60 hours per week. The work hours generally were longer for experimental work. Often student got interested in the experimental work and would spend more time to obtain data.

It was noticed that most students like flexibility of work hours. A rigid work schedule however is required for experimental work as team members have to work together in the experimental project. Students appreciated the initial training and supervision for experimental work. They showed a tendency to work more independently as they got familiar with the setup. The interaction with graduate mentor was very useful to the students. The students sought advice and input from the graduate mentor on continuous basis. 80% student expressed satisfaction about their work

There were several challenges that were faced by students. These challenges include time management, working with the group members, and learning new techniques in a short time.

Some students also complained about tedious work and poor working environment. This reflects on the pressure under which the university faculty works on research projects where a need to deliver research results in time happen to be a very important factor.

## Lesson Learned

The summary of the lessons learned from working with undergraduate researchers are interesting and are given below. Graduate mentors need to be trained to work and manage with undergraduate. Due to the limited time the undergraduates need to learn in short time and work. This needs several preparatory materials that are useful for the novice undergraduate researcher. Graduate mentors are important in providing essential help and day to day guidance in learning the research material. For this, graduate students who are mentoring the undergraduates need to be appropriately trained. Often the research project may not be suitable to undergraduate due to complexity and other issues such as safety. However if the faculty is willing to modify their research program to accommodate undergraduates then there are benefits to the students as well as to faculty. The research program can be student friendly if it is designed to cater undergraduate needs. Faculty direct interaction is required with regular weekly meeting for the fruitful participation of the undergraduate researcher.

At the beginning of the project clear definition of the project requirement, expectations and possible problems should be provided to the undergraduate researcher to get well them well prepared. It is important to provide enough information and literature for the project. Safety and laboratory training required before start of experimental work should be given at the beginning of the project. As a part of communication, written reports are required every two weeks on the progress of the work. It is important that faculty and Graduate mentor attend student presentations and make important positive comments.

**Bibliography**


1. Boyer Commission on Education of Undergraduates in the Research University. 1998. *Reinventing Undergraduate Education: A Blueprint for America's Research Universities*. New York, New York
2. K. B. Schowen, K.B. 1998. Research as a critical component of the undergraduate educational experience. *Assessing the Value of Research in the Chemical Sciences*. National Research Council Report, National Academy Press: 73–81.
3. A. L. Zydney, J. S. Bennett, A. Shahid, K. W. Bauer Impact of Undergraduate Research Experience in Engineering *Journal of Engineering Education* 151-157 April 2002.
4. L. Reisberg, Research by undergraduates proliferates, but is some of it just glorified homework? *Chronicle of Higher Education*. May 22 1998.