# AC 2009-1897: PROMOTING UNDERGRADUATE RESEARCH IN ECE (PURE): CONNECTING UNDERGRADUATES WITH GRADUATE RESEARCH MENTORS

**Kuang Xu, University of Illinois, Urbana-Champaign**
Kuang Xu is a senior in Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign. He conducted research on PAPR reduction for beamforming OFDM networks under Dr. Douglas L. Jones during his Junior year. He is currently working on peer-to-peer live streaming under Dr. Bruce Hajek. He is Director of the Promoting Undergraduate Research in ECE (PURE) program.

**Elizabeth Van Ruitenbeek, University of Illinois, Urbana-Champaign**
Elizabeth Van Ruitenbeek is an Electrical and Computer Engineering graduate student at the University of Illinois at Urbana-Champaign. She conducts computer security research under the direction of Dr. William H. Sanders. She participates in the Promoting Undergraduate Research in ECE (PURE) program as a graduate research mentor.

**Promoting Undergraduate Research in ECE (PURE):**
**Connecting Undergraduates with Graduate Research Mentors**

**Abstract**

When undergraduate engineering student Kuang Xu noted first-hand how difficult it was for underclassmen to get started in engineering research, he decided to do something about it. Leading a student initiative to bring research opportunities to freshman and sophomore electrical and computer engineering (ECE) students, Xu directed the creation of the Promoting Undergraduate Research in ECE (PURE) program.

The primary aim of PURE is to provide motivated undergraduate students with research opportunities while they are freshmen and sophomores.  At the beginning of the semester, PURE actively recruits both graduate and undergraduate students and facilitates the mentor-mentee matching process.  Then, over the course of the semester, the graduate student research mentor guides the undergraduate student through an educational research project.  For many undergraduate participants, PURE provides their first real exposure to engineering research.

After favorable response from interested students, the PURE pilot program was launched at the University of Illinois at Urbana-Champaign in Spring 2008.  During this semester, 22 undergraduates were mentored by 11 graduate students.  Well-received by undergraduate and graduate students alike, the PURE program continued in Fall 2008.

This paper will first explain the motivation and vision for PURE.  The paper will describe the structure of the PURE program, providing detailed timelines of the program implementation. Then the paper will analyze PURE program participation to date and explore the motivations of the program participants.  Although no participants are paid for their involvement with PURE, both the undergraduate mentees and their graduate student research mentors benefit from participating in PURE.  Finally, the paper will describe the future of PURE as ownership of the program transitions from the founding undergraduates to the department.  Even as the program grows and evolves, PURE will continue to strive to match motivated underclassmen with graduate students who are passionate about research and mentoring.

**Introduction**

The Promoting Undergraduate Research in ECE (PURE) initiative was established to address the dilemma facing undergraduate students who are enthusiastic about conducting research.

Underclassmen eager to participate in engineering research early in their degree program face roadblocks due to their inexperience.  With limited funding and resources, faculty members are generally less likely to provide research positions for first- and second-year students who often lack technical skills and advanced coursework.  When freshman and sophomore students approach professors about research opportunities, most students are advised to take more advanced courses in specific areas in order to qualify.  In a Fall 2007 survey conducted by PURE, undergraduate students repeatedly expressed the need for a way to connect with the research opportunities available to them.

When students become juniors and seniors, they may more readily be able to participate in undergraduate research. However, some students come to realize that either research or the specific subject area is quite different from what they expected, and it is too late to change direction. With little sense of how engineering knowledge is applied outside the classroom, and thus little awareness of their true research interests, students choose technical elective classes and research projects based largely on vague uninformed intuition. Even the students who find their research work interesting may have difficulty concentrating on research while balancing the heavy course load common for third- and fourth-year engineering students.

Bringing research opportunities to freshman and sophomore students eager to begin research would enable the students to make more informed career decisions. Early involvement in research would also prepare freshman and sophomore students to perform more advanced and higher quality research as juniors and seniors than would otherwise be possible.

**Related Work**

There has been extensive research on the impact of undergraduate research on education and student retention[1,2,3]. Studies have shown that undergraduate research participants are more likely to pursue graduate education. For example, Lapatto examines the hypothesis that undergraduate research enhances the educational experience of scientific undergraduates, finding that over 83% of 1,135 participants began or continued to plan for postgraduate education in the sciences[1].

Most of the literature on undergraduate research focuses primarily on the implications of undergraduate research experiences, and few present a detailed organizational framework to make such research opportunities available to undergraduate students. Nagda et al. describe the Undergraduate Research Opportunities Program (UROP), run by the College of Literature, Science, and the Arts at the University of Michigan[2]. Like many other undergraduate research programs run by universities in the United States[4,5,6], UROP is administered by the University of Michigan and relies mainly on faculty members to provide research opportunities[2,7].

Unlikely most undergraduate research programs, the PURE program at the University of Illinois began as a student-led initiative. The students who established PURE made the following contributions:

1) They analyzed the intrinsic difficulty facing first- and second-year engineering undergraduate students when seeking research opportunities. They also emphasized the important role of such early research involvement in a student's career development.

2) They proposed a novel organizational framework to provide early research opportunities by matching undergraduate students with graduate student mentors. They showed, based on the results from the PURE program, that the model has been successful in establishing a platform to provide both research opportunities for underclassmen and teaching and mentoring experience for graduate students.

3) They demonstrated that the PURE program can provide quality research experiences with a minimum of administrative duties and financial expenses. Hence, the model is an effective approach for student-run research initiatives or institutions with limited operating budgets.

This paper seeks to document those contributions to aid in the development of other successful undergraduate research programs.

## Vision for PURE

The core purpose of PURE is to connect first- and second-year undergraduate engineering students with meaningful research opportunities. To make such research opportunities available, the PURE program recruits graduate students to serve as research mentors. While faculty members may be unlikely to work directly with underclassmen, graduate students have expressed more interest. These graduate students volunteer as research mentors to gain teaching and mentoring experience, to obtain extra assistance with their own research work, and to help undergraduate students.

Although PURE began as a grassroots student-led initiative under the auspices of the local Eta Kappa Nu (HKN) student chapter, the long-term sustainability of the PURE program depends on successfully shifting ownership from the undergraduates who developed the program to the Department of Electrical and Computer Engineering. The continued success of the PURE program will be driven the mutual benefits to the participants, requiring only minimal academic supervision from the faculty and light administrative effort from the department program office.

## Target Participants

The PURE program participants are the undergraduate student mentees and the graduate student mentors.

PURE mentees are selected from the undergraduate electrical and computer engineering student population using an application process. In general, only first- and second-year undergraduate students are eligible to be PURE mentees. The rationale for this limitation is that third- or fourth-year students with more advanced coursework should have less difficulty in accessing existing undergraduate research opportunities, such as independent projects or research with a faculty member. However, the PURE program has made exceptions for some first-year transfer students who came from community colleges and were less advanced in the technical curriculum compared with their peers.

PURE mentors are recruited from the graduate student population. Currently, all graduate students who volunteer and have ideas for undergraduate research projects are accepted as mentors. There is little screening process, mainly due to a shortage of graduate mentors and an overwhelming number of undergraduate mentee applicants. Because the graduate students likely to volunteer to participate in PURE tend to be enthusiastic about teaching, mentoring, and helping students, the lack of a more strict screening process has not seemed to hinder the program. However, in the future, PURE hopes to attract more graduate students in the third or

fourth year of the Ph.D. program so that PURE mentors will have more experience themselves both in research and in teaching.

**Program Structure**

The PURE program is structured to facilitate semester-long undergraduate research projects, although mentor-mentee pairs may independently choose to continue projects beyond one semester. The research experience itself is guided by the individual graduate student mentor. The key contribution of PURE is the matching process to connect mentees with mentors at the beginning of each semester. PURE also provides minimal oversight during the semester and organizes end-of-semester project presentations and evaluations. The PURE program repeats each fall and spring semester.

The general structure of the PURE research program can be categorized into the following three phases.

*Phase I: Graduate Mentor Recruitment*

Graduate students serve as PURE undergraduate research advisors and guide one to three undergraduate students through a semester-long (or possibly year-long) research project. To ensure that graduate students have time to adjust their schedules and to construct a meaningful undergraduate research project, recruitment for mentors is conducted in the second half of the previous semester.

This phase begins near the middle of the semester with an information session for graduate students interested in mentoring undergraduates in research. The information session includes an introduction to the PURE program, a discussion of the benefits of being a graduate mentor, and examples of past PURE research projects. An invitation to the information session is emailed to all graduate students in the ECE department. From the information session until the end of the semester (for approximately two months), PURE collects mentor applications from graduate students. Table 1 provides a timeline for the graduate mentor recruitment process. Currently, all graduate applicants are accepted as mentors due to a shortage of graduate mentors.

**Table 1. Timeline for Graduate Mentor Recruitment**

| Date | Mentor Recruitment Process |
|---|---|
| Middle of previous semester | PURE holds an information session for graduate students interested in mentoring undergraduates in research. |
| | From the information session until the end of the semester, PURE collects mentor applications from graduate students. |

*Phase II: Undergraduate Mentee Applications*

The undergraduate mentee application phase begins approximately two weeks prior to the first class day of the semester and finishes by the end of the second week into the semester, at which

time all mentor-mentee pairs are expected to have been formed. Compared with Phases I and III, Phase II is densely packed with many tasks to be completed in four weeks. The first two weeks of the semester are especially busy. Things move quickly in this phase because recruiting undergraduate students is difficult to do before the semester begins, and yet the research projects need to begin early enough in the semester for the mentee to gain some meaningful experience by the end of the semester. Table 2 provides a detailed timeline for the undergraduate mentee application process.

In the past two semesters, the demand for participation from the undergraduate students has been significantly higher than the number of the graduate students available as mentors. Therefore a competitive screening process is necessary for mentee applications.

**Table 2. Timeline for Undergraduate Mentee Applications**

| Date | Mentee Application Process |
|------|----------------------------|
| Two weeks prior to the first day of class | All graduate mentors are asked to complete an online profile, which will be available to all mentee applicants. The profile contains a description of the mentor's research interests as well as proposed PURE research projects. |
| First day of class | Instructors for all sophomore-level and below ECE classes are asked to make a class announcement for the PURE Undergraduate Information Session. |
| | Information regarding the mentee application process is distributed via posters, department website announcements, and email newsletters of engineering student organizations. Students are encouraged to visit the PURE website and learn about each mentor's research area and proposed projects as listed in the mentor profiles. |
| Third day after the first day of class | The PURE Undergraduate Information Session provides students with information on the PURE program structure, the benefits of early undergraduate research, and examples of past PURE projects and mentee experiences. |
| Fifth day after the first day of class | The mentee application online system is open. |
| | Mentee applications are collected through an online web form system. The applicants are asked to list two preferred mentors and to write for each mentor a 300-word passage to justify that choice, discussing what they know about the mentor's research and how it matches with their own interests. |
| Twelfth day after the first day of class | The mentee application online system is closed. |

| | All mentee application information is compiled in a master spreadsheet and sent to all mentors. Based on that information, the mentors designate their top five choices of mentees.  The mentors also specify the actual number of mentees they are willing to guide (normally from one to three undergraduates). |
|---|---|
| Fourteenth day after the first day of class | The PURE administrators assign mentor-mentee pairs solely based on the order of preferences indicated by the mentee applicants and graduate mentors. If two mentors show strong preference toward the same undergraduate applicant, the committee assigns the undergraduate applicant to the mentor who was listed as the first choice of mentor in the applicant's original application. |
| | Mentors and mentees are notified of their match, and the research begins! |

*Phase III: Evaluation*

After the PURE participants are notified of their match two weeks into the semester, the mentor-mentee pairs formally begin work on a research project.  After this point, the administrative duties of PURE reduce substantially. The main goal for Phase III is to provide light supervision to ensure that all participants are fulfilling their commitments as mentors or mentees.  Also, PURE organizes a program-wide presentation session at the end of the semester where all mentee participants present their research work and describe what they have learned from the research experience. Table 3 provides a detailed timeline for the evaluation phase.

**Table 3.  Timeline for PURE Participant Evaluation**

| Date | Evaluation Process |
|---|---|
| Third week after the first day of class | Mentor-mentee pairs (or groups) have their first meeting to discuss the objectives of the semester and possible project ideas. The faculty advisor of the graduate student mentor, although not required, is encouraged to participate in the meeting and help construct a meaningful undergraduate research project. |
| Fourth week after the first day of class | Mentees are required to submit a Goal Statement describing proposed project ideas. |
| Two weeks prior to semester final exams | Mentees present their research work and learning experiences at the PURE Undergraduate Research Symposium. The symposium audience typically includes other PURE participants, ECE students, and several interested faculty members. |

| One week prior to semester final exams | Mentees are required to submit a Semester-End Program Summary, which includes a summary of their research work and experiences as well as feedback on how PURE can be improved. |
|---|---|
| | Grades for ECE 297 (mentees) and ECE 597 (mentors) are assigned for those who chose to obtain course credit for their participation in the PURE program. |

Because the PURE program structure enables an efficient use of the semester, other universities are encouraged to consider a similar program structure for starting semester-long undergraduate research programs.

**Analysis of PURE Program Participation**

The PURE pilot program was launched in February 2008 and involved 11 graduate students as mentors and 22 undergraduate students as mentees. The mentees were selected from 33 applicants.

The full-scale PURE program was launched in August 2008. Compared to the pilot program, the full-scale program extended the project length to a full semester, offered both undergraduate and graduate students optional course credit, and deployed a website containing profiles of the graduate mentors to help mentee applicants choose mentors who match their research interests. The full-scale program maintained the number of mentors at 11 and increased the number of mentees to 28. The 28 mentees including 2 returning mentees from Spring 2008 and 26 new mentees selected from 56 undergraduate applicants.

The graduate mentors who participated in the pilot program and the Fall 2008 full-scale program came from a diverse set of research areas. The following research areas were represented among the PURE mentors (with the number of mentors indicated in parentheses):
- Computer Engineering: Computer Security (4), Computer Vision (1)
- Electromagnetism: Antenna Design (1)
- Engineering Education (1)
- Physical Electronics: Computational Nanotechnology (1), Semiconductor Devices (1)
- Power and Energy (1)
- Signals and Systems: Digital Signal Processing (2), Controls (4)
- Remote Sensing and Atmospheric Science (1)

**Analysis of PURE Program Success**

What has enabled PURE to be successful as a student-initiated grassroots effort without substantial resources? PURE attracts participants because of the benefits it offers to mentees and mentors.

Based on mentee applications and end-of-semester reports for Fall 2008, undergraduate students cite six main reasons they are motivated to participate in PURE. First, PURE applicants are eager to gain hands-on engineering experience and to see practical applications of what they are

learning in the classroom.  Students want to be involved in engineering beyond their normal curricular activities.  Second, students want to discover their specific interests within the very broad field of electrical and computer engineering.  Exploring different areas through PURE research projects enables students to find what interests them and to choose appropriate areas for technical elective classes.  Third, undergraduate students value the opportunity to learn what research is and to begin to develop research skills.  Students use their PURE experience to evaluate the appeal of graduate school and to prepare for doing research in graduate school.  Fourth, PURE applicants express a general enthusiasm to learn and discover.  PURE enables these students to work on research projects that can capture that enthusiasm.  Fifth, undergraduate students seek the professional networking opportunities PURE offers.  PURE enables a direct connection between the undergraduate and the graduate mentor.  The mentee may also benefit from interactions with other graduate students and even professors.  The sixth and final reason undergraduates are motivated to be PURE mentees is that it is fun.  Students enjoy working on interesting and challenging projects.

Based on mentor feedback surveys, graduate students are motivated to participate as PURE mentors for four primary reasons.  First, graduate mentors cite the desire to help undergraduate students by exposing them to research, motivating them to pursue graduate school, and providing a valuable learning experience.  Some mentors participated in undergraduate research themselves and want to give others that opportunity.  Second, graduate mentors participate in PURE to gain experience in teaching and mentoring students.  This is a particularly attractive benefit to graduate students who plan to become professors.  Third, graduate students appreciate how motivated undergraduates can provide research assistance.  Some PURE undergraduate mentees work on small side projects that complement or extend the research of the graduate research mentor.  Finally, graduate students volunteer as PURE mentors because it is fun.  The mentors enjoy working with the bright and highly motivated undergraduate students who apply to be PURE mentees.  In the Fall 2008 end-of-semester mentor feedback survey (with 10 of the 11 mentors responding), 90% of respondents agree or strongly agree that they want to be a PURE mentor again in the future, and 90% of respondents agree or strongly agree that they would encourage other graduate students to be PURE mentors.

PURE also indirectly benefits the faculty in the department.  A graduate student mentor commits to a semester-long PURE research project with an undergraduate student.  This semester project can be a good opportunity to identify exceptional undergraduate students who can later transition into undergraduate research positions under faculty members.  PURE provides a low-risk opportunity to evaluate the potential of undergraduate researchers.

What value does PURE bring to the Department of Electrical and Computer Engineering?  PURE fulfills two unique purposes.  First, PURE functions as an advocate for early undergraduate research involvement.  Second, PURE provides a valuable service in connecting motivated undergraduate students with suitable graduate research mentors.  The result is that the PURE research program enhances the undergraduate education offered by the department and helps the department produce graduate students who are well prepared to direct research as professors.

**The Future of PURE**

The creation of the PURE research program was first proposed[8] in October 2007 by a group of undergraduate students in the Alpha Chapter of Eta Kappa Nu (HKN), an ECE honor society. The PURE program was then implemented by a committee of HKN students. This effort was led by HKN member Kuang Xu.

The Spring 2008 pilot program and the Fall 2008 full-scale program were organized by the HKN students. Starting in Spring 2009, the majority of the administrative duties of the program will be transferred to the Department of Electrical and Computer Engineering. Maintaining PURE will require only minimal resources from the department, and the transition of ownership will help sustain PURE long after the founding students have graduated and left the university. An advisory committee of students will remain involved with PURE to focus on further improvements to the program. For example, more data could be collected to examine how well the undergraduate students performed research to the level they expected or to the level the graduate student mentors expected of them.

Because many more qualified undergraduate students apply to be mentees than there are graduate student mentors who can work with them, PURE is continually working to recruit more mentors so that more undergraduate students can benefit from the research experience. However, PURE is also dedicated to maintaining the quality of the program. Even as the program grows and evolves, PURE will continue to strive to match motivated underclassmen with graduate students who are passionate about research and mentoring.

**Conclusion**

Promoting Undergraduate Research in ECE (PURE) provides valuable research opportunities to undergraduates by pairing them with graduate student mentors. PURE is implemented on a semester timeline that provides undergraduate engineering students with meaningful exposure to research. Graduate mentors also benefit from the opportunity to gain teaching and mentoring experience as well as assistance with their research. As program ownership shifts from the founding undergraduate students to the department, PURE remains committed to providing early undergraduate research opportunities.

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**Appendix: More Information Available at the PURE Wiki**

PURE Wiki: *https://wiki.engr.uiuc.edu/display/PURE/Home*

The PURE Wiki contains
- general information about the PURE program (including a description of the mentee application process)
- active mentor profiles (with a photo and a research summary for each mentor)
- program feedback (a summary of the responses to mentor and mentee feedback surveys)
- the PURE archive (past end-of-semester presentations and profiles of past mentors)