AC 2008-848: IEEE'S RWEP PROGRAM TO RECRUIT AND RETAIN FIRST YEAR STUDENTS IN ELECTRICAL ENGINEERING, COMPUTER ENGINEERING AND COMPUTER SCIENCE

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IEEE's RWEP Program to Recruit and Retain First Year Students in Electrical Engineering, Computer Engineering and Computer Science

Abstract

U.S. enrollment in undergraduate programs in electrical engineering (EE), computer engineering (CE) and computer science (CS) has declined significantly in recent years. Women remain under-represented in undergraduate EE, CE and CS programs—recently, they comprise an even smaller proportion of the overall shrinking enrollment. EE, CE and CS are the three primary fields of interest to the IEEE. IEEE is an international organization with nearly 370,000 members world-wide. In 2007, IEEE launched the Real World Engineering Projects (RWEP) program aimed at recruiting and retaining undergraduate students in EE, CE and CS programs. The RWEP program is a competitive, peer-reviewed award process that solicits hands-on, team-based, first-year projects that focus on real-world problems whose solutions benefit society. IEEE disseminates these projects to faculty worldwide for their use in the classroom. These projects make EE/CE/CS significantly more exciting and relevant to first year students and illustrate how the work of professionals impacts society. IEEE expects that the RWEP program will help realize increased student enrollment and retention in EE/CE/CS undergraduate programs—with an even greater impact on students from under-represented groups. Preliminary results support this hypothesis.

Background and Motivation

U.S. enrollment in undergraduate programs in electrical engineering (EE), computer engineering (CE) and computer science (CS) has exhibited a significant decline in recent years. From 2001 to 2006, enrollment in undergraduate CS programs dropped 20% from 33,695 to 27,062 full-time students[1]. From 2001 to 2006, enrollment in undergraduate EE and CE programs dropped 27% from 102,943 to 75,302 full-time students[1]. EE, CE and CS are the three primary fields of interest to the IEEE. IEEE is an international organization with nearly 370,000 members world-wide[2].

In addition to the overall declining enrollment, women remain significantly under-represented in undergraduate EE, CE and CS programs. Moreover, their small representation has recently eroded further. In 2006, women earned only: 14.2% of the EE bachelor's degrees (down from 14.8% in 2002); 11.2% of the CE bachelor's degrees (down from 12.8% in 2002); and, 13.7% of the CS bachelor's degrees (down from 17.9% in 2002) [1,3].

In 2007, IEEE launched a $400,000 program aimed at recruiting and retaining undergraduate students in EE, CE and CS programs. The IEEE Real World Engineering Projects (RWEP) program is a competitive, peer-reviewed award process that solicits hands-on, team-based, first-year projects that focus on real-world problems whose solutions benefit society[4]. For example, a potential signal processing project might have the students implement arrhythmia detection algorithms and discover how computational complexity affects the real-time constraint that is critical to an implantable device's ability to save lives. IEEE makes the selected projects available to the world's EE/CE/CS faculty through the IEEE Education web portal.

Faculty's use of these projects makes EE/CE/CS significantly more relevant to first year students and illustrates how the work of professional engineers and computer scientists impacts society. The projects allow students to discover the importance of contemporary EE/CE/CS problems and elicit excitement about creative solutions. There are several novel aspects of the RWEP program's approach.

- The projects address real, contemporary engineering challenges; consequently, they are more meaningful than many first year projects that address only "toy" problems.
- The projects demonstrate "how" and "why" the technical methods work and are not mere "recipes."
- Underlying complex principles and concepts are made tractable by the experts who develop the projects; moreover, engineering solution strategies and trade-offs are illustrated through the projects.
- Each project explicitly describes how the problem and its solution impact society; this is an important motivator for students—particularly women students. This societal benefit dimension portrays EE/CE/CS in a way that is usually considered to apply only to disciplines like biomedical engineering and environmental engineering.
- The projects promote a more interactive, engaged approach to the first year education experience. Students work together on teams to solve the problems presented; they also interact with the faculty as they design and implement their solutions. This fosters a sense of community that is not only more enjoyable, but has also been shown to be of importance to student retention and learning.

RWEP is a unique program that leverages IEEE's ability to persuade faculty to engage in creating and implementing a more inspiring approach to early engineering education. IEEE expects that this approach will benefit students, faculty and the EE/CE/CS professions worldwide.

IEEE RWEP Program

Educational Activities (EA) is the IEEE entity responsible for the development and management of the RWEP program. EA is comprised of full-time IEEE staff members and IEEE volunteer members working together on IEEE's education programs.

The RWEP program employs a two-step, peer-reviewed (double-blind) process for soliciting and awarding the projects. First, abstracts are solicited and reviewed. Selected abstracts are then invited for proposal submission. Next, proposals are reviewed. Finally, selected proposals are awarded and authors are invited to submit the full project implementation.

The abstract submission is a one-page document that includes the following.

1. Project title.
2. Introduction to the technical problem addressed by the project.
3. Impact of the problem's solution on society.

4. Description of the hands-on project: what the students will do and what they will discover (including underlying concepts, strategies employed, and trade-offs observed).
5. One figure that illustrates the problem/solution.

An example abstract is provided to authors on the IEEE RWEP web site[4]; it is shown here in Figure 1.

Signal Processing: Arrhythmia Detection Algorithms for Implantable Cardioverter Defibrillators

Introduction and Impact: The heart is controlled by electrical impulses that signal the heart's four chambers to contract, each at the proper time. The heart works in an endless contract-relax/contract-relax cycle. An average heart beats 100,000 times a day, pumping some 2,000 gallons of blood through its chambers to the rest of the body and then back to the heart. Over a 70-year life span, that adds up to more than 2.5 billion heartbeats. The normal heartbeat cycle is described by the "PQRSTU" wave shown in Figure 1 (below, left). An arrhythmia is an irregular heartbeat caused by disordered electrical activity that disrupts the normal contract-relax cycle and results in rapid, unsynchronized, uncoordinated contractions, see Figure 1 (below, right). When this occurs, little or no blood is pumped from the heart; the person can faint, suffer chest pains, and even sudden death may occur. The heart can be converted back to a normal rhythm with an electrical shock (called a "therapy"). An electronic device called an implantable cardioverter defibrillator (ICD) administers the electric shock to the heart; it is an effective treatment for people at high-risk. The ICD constantly monitors heart rhythm; it must accurately and quickly detect when the rhythm becomes abnormal and determine whether a therapy is required—the ICD's built-in capacitor administers the therapy when needed.

Hands-on Project: The students will use Matlab to program two arrhythmia detection algorithms employed in ICDs. They will evaluate their algorithms using real electrocardiograms (ECGs) and learn about the statistical performance measure called sensitivity. The first, simpler algorithm is rate-based and relies on a first derivative of the ECG; it is limited in its ability to properly distinguish arrhythmias that require therapy (VT) from those that don't (SVT). The second, more complicated algorithm uses additional information to better discriminate VTs and SVTs. The comparison of the two algorithms will illustrate the tradeoff between algorithm speed vs. accuracy (faster/less accurate vs. slower/more accurate). *Through their comparisons, the students will discover the impact of algorithm computational complexity on the real-time constraint that is critical to the ICD's ability to save lives.*

An example of further reading for this project is the recent article that describes the ethical issues surrounding a manufacturer's unwillingness to recall defective ICDs.

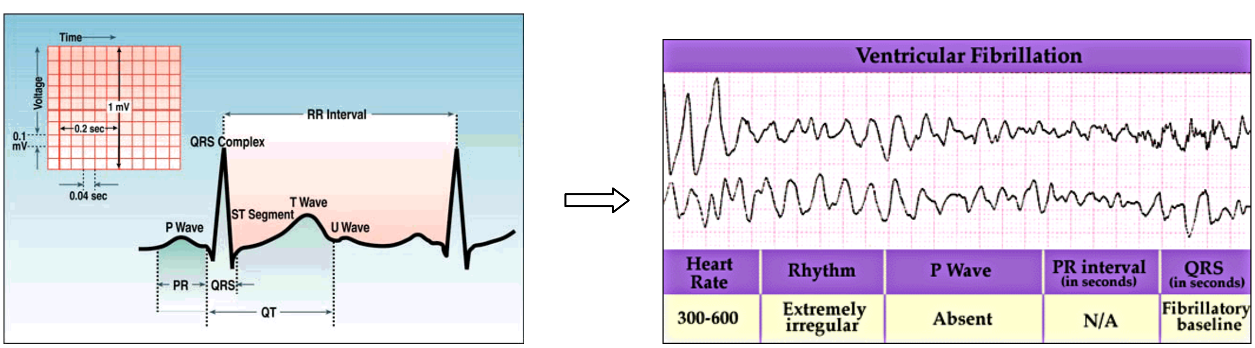

Figure 1. A normal heart rhythm (left) is described by the "PQRSTU" wave. A ventricular fibrillation arrhythmia occurs (right) when abnormal electrical activity upsets the heart's normal contract-relax cycle.

For selected abstracts, the authors were invited to submit a full proposal that consisted of a five-page document that elaborates on the key elements of the abstract. The review criteria employed for the abstracts and proposals are threefold: relevance, quality, and discovery.

- ***Relevance:*** Does the proposed project address a problem whose solution(s) benefits society? Is the project presented in the context of a real-world, contemporary application? Are these connections made explicit in the proposed project?
- ***Quality:*** Is the proposed project described in a straightforward, organized, and complete manner? Are the proposed project description and methods accurate, clear, and concise? Is the proposed project tractable for first year EE, CE and CS students?
- ***Discovery:*** Does the proposed project result in student discovery of an underlying principle or concept? Does the proposed project illustrate strategies and trade-offs that are important in the engineering problem solving process?

Proposals that are selected for award are then developed into full project implementations. Each completed project includes the following.

1. An ***abstract***.
2. A ***background lecture*** that motivates and introduces the problem and provides the necessary technical background (for presentation to the students). The impact of the problem's solution on society is demonstrated and illustrated in the context of the real-world, contemporary application.
3. A ***student project assignment*** that recaps the problem and details the hands-on project to be conducted (for distribution to the students who would conduct the project). This assignment details what the students will do and discover.
4. A ***faculty project description*** that details the hands-on project (for distribution to the EE/CE/CS faculty who would use the project in class). This description includes a description of the resources needed to conduct the project and explicit directions on how to build/assemble the system (if applicable). This description also includes the necessary data, code, or other methods for executing the project. This description also elaborates the expected problems, strategies, trade-offs, and results. Finally, this description lists the learning objectives for the project.
5. A ***project report solution*** that provides an example to the EE/CE/CS faculty of a successful, complete, student project report. The sections of the project report include: problem definition, methods, results, and conclusions. The report includes graphs and data, the observed trade-offs, the employed strategies, and what was discovered.
6. A ***summary lecture*** reviews the problem, the methods for solving the problem, the trade-offs and strategies involved in the solution, and what was discovered (principles, concepts, etc.; this is for presentation to the students). The summary lecture concludes with the reconsideration of the real-world application and its benefit to society.
7. A list of ***exam/assessment questions*** includes about 10 short answer questions and 2 design questions. These questions align with the project learning objectives.

Each author of an RWEP award receives the following:

- an honorarium of $5000 US;
- a two-year term as a member of the IEEE Educational Activities Advisory Panel; and,

- an invitation to submit a manuscript describing the project for consideration by the editors of a special issue of the IEEE *Transactions on Education* dedicated to the awarded projects.

The projects and their authors are publicly recognized and promoted by IEEE on its web portal, in its premier education journal, and at its annual Educational Activities Award event. IEEE-sponsored awards are highly valued by EE/CE/CS educators and professionals across the globe; consequently, authors are motivated to submit high quality project ideas to the RWEP program. Faculty are motivated to utilize the RWEP projects in their curriculum since the IEEE-sponsored material is accurate, complete, exciting and described as a "best practice" in engineering education.

IEEE also fosters an online community of the RWEP faculty authors and users. The goals of this aspect of the RWEP program are to: provide opportunities for collaboration between IEEE members with similar interests; report on the impact of the projects on first year students; reflect on ways to improve individual projects; and, create a supportive EE/CE/CS education environment.

Outcomes and Related Preliminary Results

The RWEP program was launched in April 2007 with the first solicitation for projects. In the abstract submission phase, 34 abstracts were received. The abstract authors hailed from 12 different countries; approximately 29% of the authors were women. 18 of these abstracts were invited for proposal submission (6 countries, 28% women); 15 were received by the proposal submission deadline (5 countries, 27% women). A panel of 8 experts from academia and industry performed the two reviews. Our panelists brought a wide range technical expertise, education experience, and geographical and cultural diversity to the review process.

In October 2007, 8 proposals were awarded (2 countries, 38% women) and are currently under development for full project implementation and publication in spring 2008. These technically diverse proposals span seven technical EE/CE/CS categories: circuits, communications, computer hardware/architecture, controls, human computer interaction, power electronics, and signal processing. The eight project titles are as follows.

- Error Correction Codes for Wireless Communication Systems
- Audio Forensics: Solving a Crime using Digital (Audio) Signal Processing
- Manipulating Everyday Objects With Prosthetic Hands
- Solid State Lighting for the Developing World
- HCI Alternatives using the Nintendo Wii
- Power Electronics/System: A Look at Renewable Energy
- Smarter Vehicles
- Feedback Controlled Brushless DC Motor

IEEE anticipates several outcomes as a result of the RWEP project; however, the expected student outcomes are paramount. IEEE will collect assessment results from faculty who use the projects; the following outcomes are expected.

- Higher retention to degree (undergraduate EE/CE/CS) rate for ***all*** undergraduate students—with the largest improvements occurring for students from under-represented groups.
- Improvements in student performance, self-confidence, satisfaction, perceived ability, and importance of engineering.
- Significantly higher enrollments of women in undergraduate EE/CE/CS degree programs.

Although it is too early to assess the impact of the IEEE RWEP program on these student outcomes, prior results from several studies offer evidence that these improvements will occur[5-7]. In particular, there are some recent results from a first year course for EE/CE/CS students at Virginia Tech that indicate significant positive outcomes will be realized. Virginia Tech developed a completely new version of a first-year, required course for students entering electrical engineering, computer engineering and computer science. The revised course emphasized team-based, hands-on, discovery-based projects that address real-world, contemporary problems: 8 faculty presented the projects and interfaced with the student teams as they designed and implemented their solutions.

The primary student outcomes that were evaluated after one semester are as follows[8].

- The level, amount and quality of work that the students performed increased substantially over the old version of the course.
- The students' exposure to germane EE/CE/CS problems, solutions, concepts and tools increased dramatically.
- Student course retention rates increased: 100% of the women and 97% of the men who enrolled in the new course completed it.
- Student enrollment in the second semester of the new course increased: women's enrollment increased 60% (from 15 to 24) and men's enrollment remained steady.
- Students were administered a questionnaire at the beginning of the new course; it was repeated at the end of the course. On the questionnaire, the students were asked to rate their level of agreement or disagreement with seven questions pertaining to EE/CE/CS. Students exhibited the lowest level of agreement/strong-agreement with the statement: "I feel like I am part of an EE/CE/CS community here at University X"; at the beginning of the course only 35.1% of students agreed/strongly-agreed with this statement. However, by the end of the course, 53.8% of students agreed/strongly-agreed with this statement—a significant improvement.
- The beginning questionnaire was also administered to students in the old version of the course. 68.0% of students in the old version of the course strongly agreed with the statement: "EE/CE/CS engineers perform work that is important to society." However, 81.1% of students in the new version of course strongly agreed with this statement on the beginning questionnaire. Similar to the old version, students in the new version of the course experienced one lecture and one lab before completing the beginning questionnaire. The first lecture in the new version of the course described all of the projects to be investigated during the semester—and the impact of each project's problem/solution on people/society was explicitly described.

Future

IEEE EA will issue the second call for proposals in spring 2008. By the end of 2008, the RWEP will have completed its $400,000 startup phase and become a sustained program within IEEE EA. IEEE plans to increase the resources it allocates to its education initiatives so that RWEP is funded under the normal EA operating budget. In addition to acquiring and disseminating the second round of projects, RWEP will focus on developing and implementing its assessment plan in 2008.

References

[1] M.T. Gibbons, "The Year in Numbers," ASEE's 2006 ProfileEng, www.asee.org/colleges
[2] http://www.ieee.org
[3] "Databytes," ASEE Prism Magazine, September 2004.
[4] http://www.ieee.org/web/education/university/RealWorldEngineering/index.html
[5] D. W. Knight, L. E. Carlson and J. F. Sullivan, "Staying in Engineering: Impact of a Hands-On, Team-based, First-Year Projects Course on Student Retention," *Proceedings of the ASEE Annual Conference and Exposition*, Nashville, Tennessee, June 2003
[6] Keynote address to IEEE Board Series Meeting by Dr. Bernard Amadei, EWB Founder and Professor CEE at CU, Scottsdale, AZ, February 2006.
[7] AAUW Educational Foundation Report on "Tech-Savvy: Educating Girls in the New Computer Age," Commission on Technology, Gender and Teacher Education, 2000.
[8] A. E. Bell (PI of NSF project and Course Leader), preliminary results from project supported by NSF CCLI award 0633496; see publication in this 2008 ASEE conference proceedings on one of the course projects, first author S. Raman.