2006-1371: EXTENDING ELECTRICAL ENGINEERING RESEARCH TO UNDERGRADUATE STUDENTS THROUGH A MULTI-MEDIA TECHNOLOGY INTERNSHIP PROGRAM

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Extending electrical engineering research to undergraduate students through a multi-media technology internship program

Abstract

A means by which electrical engineering research can be effectively extended to undergraduate students through the use of a university-wide multi-media technology internship program is described. A group of ten full time students participated in the program over a period of ten weeks during the summer. Undergraduates were introduced to research through the task of developing electronic portfolios describing research programs associated with faculty members. This conduit created a one-on-one faculty-to-student interaction, which enabled an environment in which the student could begin to understand the essential ideas behind doing research at a university. In addition to engineering, a variety of other disciplines were represented, including chemistry, economics, and literature. Each student/faculty partnership approached the experience from different directions. This provided a unique atmosphere for an electrical engineering undergraduate student to learn about university research in a broader sense. The approach taken by the electrical engineering faculty/student partnership involved exposing the undergraduate to a small scale research project designed to reflect typical activities experienced by graduate students. The student went through the entire cycle of design, simulation, fabrication, and test of a working device prototype. Through this approach, the student experienced a microcosm of graduate school while interacting with graduate students, experiencing the difference between laboratory and simulation work, and developing technical writing skills through the development of the electronic portfolio.

Introduction

A program referred to as "Research on Research" has been developed to expose undergraduate students to academic research. The program is instituted through the Technology Enhanced Learning & Research office (TELR) at the university. At the heart of TELR is the "TELR Design Team": a team of skilled professionals comprising instructional technologists, visual and web designers, web programmers, accessibility specialists, and researchers. TELR oversees projects in support of the instructional mission of the university including academic research, multimedia projects affiliated with a credit-bearing course, multimedia training projects for faculty, staff and students, etc.

The "Research on Research" program provides a means for faculty members to extend their research into the undergraduate learning environment via technology. Students are supported by TELR to collaborate with a faculty member during the summer period to develop a multimedia research portfolio documenting research. The entire program was hosted inside the "Digital Union": a TELR office space outfitted with both hardware and software multimedia tools. The Digital Union served as a meeting place where the students interacted with the TELR design team in a workshop environment.

The undergraduates worked one-on-one with a faculty member and explored some aspect of the faculty member's research. This exploration was documented in what is called an "electronic portfolio" or "ePortfolio". The ePortfolio is a stylized website that serves as research documentation that has been collected and organized in a user-friendly presentation. The undergraduate students documented their ten week experiences in the ePorfolios, turning the task of research documentation into an interesting multimedia project.

Of the ten 2005 research participants, the electrical engineering partnership was unique in that it exposed the undergraduate to a small scale research project that mimicked typical graduate student activities as a means of educating the undergraduate in graduate level academic research. This project was designed so that the student could perform most of the research independently. The small scale research project dealt with designing, simulating, building, and testing a prototype "Frequency Selective Surface" (FSS) as a means of eliminating "Cell Phone Noise Pollution" in unwanted areas. The ultimate goal of the project was to block electromagnetic signals in the cell phone frequency range using this FSS. The project not only trained the undergraduate how to build and test a prototype FSS, but taught the undergraduate how to conduct research that involves four major steps: (1) concept/design, (2) simulation, (3) fabrication, (4) test. Technical writing and reporting is covered through the development of the ePortfolio. The overall concept of the Research on Research program is shown in Figure 1.

This paper will describe just how the ePortfolio was used to organize the participants' research and how it addressed common barriers to undergraduate research. The paper will then explain in detail the miniature electrical engineering graduate research project. The means by which this small scale undergraduate research project served as a microcosm of graduate school research will be conveyed.

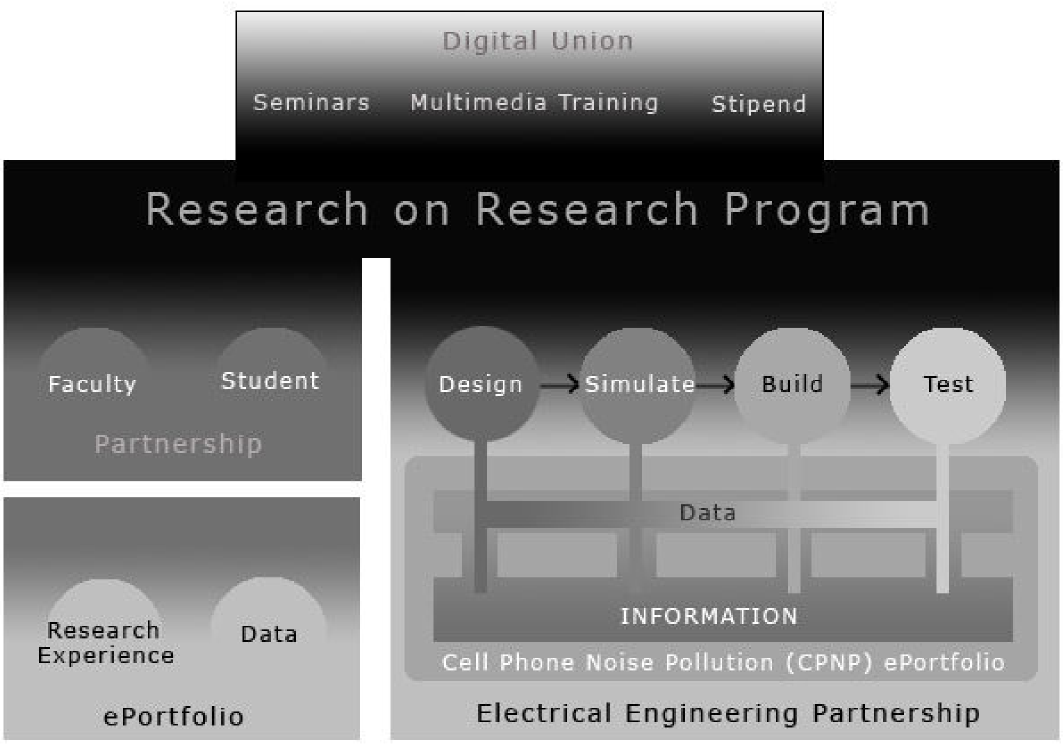

Figure 1- The Research on Research Concept Layout.

Fundamentals of the Research on Research Program

The program invited faculty and undergraduate students from any department in the university to form partnerships. Four groups were from the College of Engineering and six from the College of Arts and Sciences. The field of study of the participants and their faculty, along with their fundamental research question, are shown in Table 1. As shown in Table 1, each partnership addressed a research project that could be linked to a societal problem. This helped the undergraduate student obtain a sense of relevancy of his/her research. This link to societal problems is an important issue with respect to graduate school retention in higher education and was an important factor in choosing the partnerships that would participate in the program.[1] Students were given a summer stipend, allowing for the freedom of focus for the duration of the ten weeks.

Faculty	Student	Question
Chemistry	Chemistry	How can organic synthesis be used to improve cancer drugs?
Economics	Mechanical Engineering	Do asset market bubbles really exist?
Molecular Genetics	Molecular Genetics	Is the tyrosine residue of the Mps1 protein important in Mps1 phosphorylation and centrosome localization?
Mechanical Engineering and Industrial, Interior & Visual Communication Design	Mechanical Engineering	How can system architecture be modeled effectively as a supplementary teaching tool to engineers?
City and Regional Planning	Industrial, Interior & Visual Communication Design	What are the human-centered guidelines of an optimal environmental navigation system?
Electrical and Computer Engineering	Electrical and Computer Engineering	Can we selectively block signals at cell phone frequencies?
Civil & Environmental Engineering & Geodetic Science	Civil & Environmental Engineering & Geodetic Science	How will PCS reinforcement in circular columns perform?
Surgery	English	How and why do transplant recipients frequently develop skin cancers?
History	Art and Spanish and Portuguese	How can oral history be used to give a more accurate depiction of the past?
Physical Activity and Educational Services	Physical Activity and Educational Services	What are the perceptions of barriers associated with distance ed

Table 1 - 2005 participants and their research questions.

As students learned about their professor's research, they documented their progress in the ePortfolio. A website style ePortfolio was used as it facilitated wide access from any location across the internet and naturally focused the research effort of the faculty/student partnership by channeling the research data into website style documentation. This way, by the end of the ten week period, each student had a lasting description of what they learned over the summer which was presentable to a wide audience.

The investigation of an active research problem, with the ePortfolio as a segway, gave the entire research project an atmosphere of excitement and discovery. It has been argued that experience in this atmosphere is a strong attractor for students seeking to learn about graduate school.[2]

The Research on Research program held seminars to further educate the undergraduates on a range of discussion topics. These seminars, called round-table discussions, took place in the Digital Union. As shown in Table 2, the program hosted a seminar each week for the students, with guest discussion members including the university provost, department chairs, and faculty professors from the partnerships. Each guest speaker lent their own experienced knowledge to the discussions, and in doing so created a very unique forum for question and answers.

The Image of the Researcher	Week 1
How Universities Work	Week 2
Research Questions	Week 3
Research Methods	Week 4
Research and Undergraduate Teaching	Week 5
Research policy	Week 6
The Discipline of the Disciplines	Week 7
Research Mistakes	Week 8
Change of plans	Week 9

Table 2 - Round-Table Discussion Topics.

The Digital Union was also the space that the ten students met everyday and worked with the TELR design team. The TELR specialists trained the undergraduates in using software, hardware, and printed multimedia tools, digital video cameras, and posters to create and promote their ePortfolios. Training sessions aimed at equipping the undergraduates with the skills needed to create quality research ePortfolios were conducted. The students learned to make use of "contrast" and "clarity" in order to best present research information. As far as clarity is concerned, the undergraduates held mock presentations in order to test how well their ePortfolios presented the information. These mock presentations also prepared the undergraduates for the final presentations held at the end of the internship and that would showcase the final complete ePorfolios.

The Electrical Engineering Partnership

The electrical engineering partnership approached this internship opportunity from the point-of-view of providing a research experience for the undergraduate where the student could be exposed to a small scale research project that encompasses many of the aspects of a graduate student research program. To serve this purpose, the goal was to have the undergraduate student experience a project involving (1) concept development and design, (2) simulation, (3) fabrication, and (4) test. Technical writing was covered via the ePortfolio. A practical sense was built into the project as this has been argued to be helpful in revitalizing undergraduate education.[3] This would both teach the undergraduate how to perform academic research and would give the undergraduate a glimpse of graduate school for the first time.

The partnership wanted to focus on a very practical problem that affected society. The research question asked by the electrical engineering partnership was, "Can we selectively block signals at cell phone frequencies in order to solve the problem of cell phone noise pollution?" Cell Phone Noise Pollution (CPNP), the inappropriate ringing of cell phones in auditoriums, libraries, theatres, is a suitable problem requiring a technological innovation or invention to solve reasonably. The electrical engineering approach to this question involved the research into the development of a prototype device that could address this question. The prototype would be created using the following steps:

1. Design – the problem requirements turn into device specifications
2. Simulate – the device is then modeled and tested using a simulator
3. Build – the device is then implemented physically
4. Test. – the device is experimentally tested in a laboratory setting

The partnership decided to create a "Frequency Selective Surface" (FSS) - an engineered material whose electromagnetic properties are controlled by macroscopic structural designs. The FSS was designed to stop (or pass) electromagnetic radiation like a filter.[4] FSS research is an active area of interest for many research groups worldwide.[5,6] The electrical engineering faculty/student partnership chose this area because it was amenable to creating a research experience that was a microcosm of graduate school. As shown in Figure 2, the theoretical operation of an FSS can be understood through lumped elements such as inductors and capacitors. Therefore, the undergraduate could apply his/her knowledge of circuit analysis to understand this research problem. Copper strips are arranged in a periodic fashion, each strip being half a wavelength of the design frequency. When an electric field excites electrons on the surface of the copper strips, the entire arrangement begins to resemble the circuit characteristics of a series LC circuit.

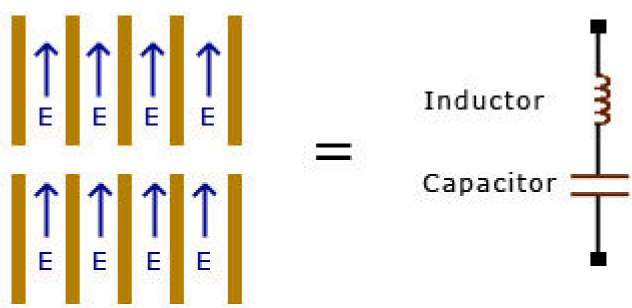

Figure 2 – A frequency selective surface is a periodic arrangement of half-wavelength resonant copper strips which couple and can then be modeled by a series LC circuit.

The brainstorming, preliminary research, and study of the theory behind FSSs showed the undergraduate how to begin solving a research problem. This project also acquainted the undergraduate with the fundamentals of FSS theory in the hopes that continued exploration of the topic will produce innovation later in the future. But in order to keep the project to a small scale, and to fit the time requirements, the design of the FSS focused on just blocking signals at cell phone frequencies. Also, due to many technical considerations, the actual prototype device built in this project was a passband FSS centered at a frequency ten times that of a cell phone. The motivation behind this modification was that a bandpass proof-of-concept design at ten times cell phone frequencies was easier to fabricate and less expensive. The theory behind both designs was the same, and the design of either one is complimentary to the other.

The next step of the research project involved exposing the undergraduate to experimental software simulations. Electrical engineering research most often uses some software simulation when building prototype devices because the cost in manufacturing is high and it is more affordable to use hypothetical models until accurate design specifications are calculated. Theoretical models are often powered by numerical computational methods, requiring fine-tune adjustment in order to achieve the design specifications. Simulation testing showed the student how to steer the experiments in the right direction. Using deduction and scientific intuition the undergraduate learned to make changes to the software model to edge the simulation results closer toward the design specifications. One such simulation tool for electromagnetics is based on the "finite element method". The student used this program to conduct over thirty five computer simulations of an FSS. The student used the simulator independently of the professor, with periodic reporting of the simulations to the professor, who then confirmed the results, and helped point the student in the proper direction. Discussion was held over key simulation results to show the undergraduate the importance of interpreting simulation results as a way of steering experiments to the end goal. The partnership desired that almost all the signal pass through the FSS at the target frequency, and that none of the signal be reflected. A quick drop off in transmitted signal around the design frequency was desired to ensure some selectivity in the device. As shown in Figure 3, at 10 GHz nearly 100% of the signal is transmitted. From the graph we see that our FSS has a 2 GHz 3dB bandwidth. For a passive FSS, the power is always conserved.

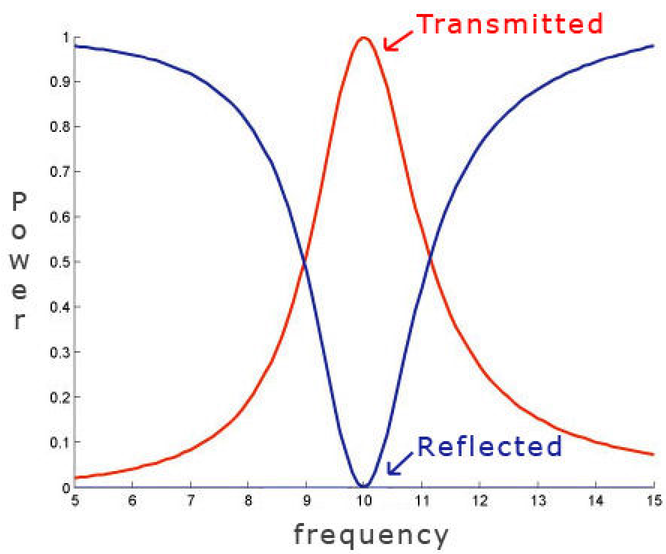

Figure 3 - Finite element method simulation result showing that the FSS is a passband filter centered at 10 GHz with a bandwidth of 2 GHz.

As part of research program, the undergraduate physically built the prototype. There were many ways to build the prototype FSS, all of them would have taught the undergraduate how to implement a design physically. The partnership used what is called a milling machine, and is a fabrication process well-suited to the manufacturing of intricate surface patterns. The milling machine etches away, or "mills", lines and shapes into a copper surface. It must be noted that an ideal FSS is two-dimensionally infinite, which would be impossible to manufacture. The partnership accepted the donation of a board that was 13.5 inches by 7 inches. The FSS was constructed using this smaller size board and the finished product is shown in Figure 4.

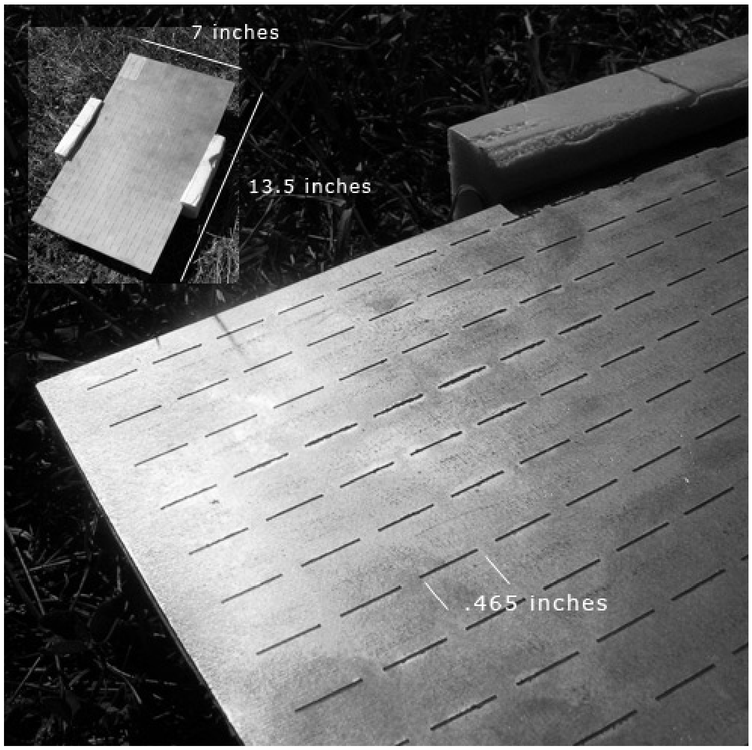

Figure 4 - Frequency Selective Surface - the individual slots measure 0.465 inches, corresponding to the half-wavelength resonant frequency after taking into account the dielectric material of the supporting substrate.

A close examination of the finished product showed very few manufacturing errors on the surface of the FSS. It turns out in testing that these small manufacturing errors slightly affected the target frequency, although this was expected. This low-cost route was optimal for the ultimate goal of the partnership and the materials donated performed excellently considering the cost. The partnership was able to create the FSS approximately one week after the simulations. Up to this point, the device designs were only conceptual, nothing had been built. Building the FSS showed the undergraduate how to manufacture the design, including programming the fabrication machinery, and brought the concept into physical existence for the first time. The manufacturing process showed the undergraduate the process of realizing a design into a prototype that can be physically tested.

Testing the FSS moved the undergraduate student into the laboratory test setting. The faculty professor trained the undergraduate how to calibrate the test equipment (vector network analyzer) and how to use it to measure the transmission and reflection coefficients of the device. The undergraduate was then left to discover ways of capturing results, and to explore the laboratory setting. Spread out over the laboratory were many graduate students and their research projects. One graduate student demonstrated how to fine-tune the test equipment to capture signals within a specific range of phases, an advanced testing technique useful for screening out noise. Other graduate students offered the undergraduate helpful advice in setting up the test bed. Yet still, many graduate students were helpful in explaining to the undergraduate many concepts which he had not yet fully understood. Working side by side with graduate student experimentalists, the undergraduate was able to pick up on the excitement of research and discovery that takes place in a graduate school environment.

It should be noted that the partnership itself resembled an excellent independent study. Early design brainstorming discussions showed the undergraduate *what* electrical engineering research is all about. The faculty professor's logical, step-by-step, approach to the simulations was a valuable example for the undergraduate to learn. Building the FSS taught the undergraduate manufacturing technique. The laboratory brought prototype testing and experimentation together with a rich graduate student interaction. The electrical engineering partnership approach was viewed very positively by the partnership itself as well as by the other participating groups.

Presentations

By the end of the ten weeks, the ePortfolios were complete, giving a lasting description of each partnership's work over the summer. The ePortfolios were then used for a live presentation. Each partnership was stationed at a different computer inside the Digital Union. For about three hours a stream of people including family, faculty, and university staff, including the University President, walked by the stations and learned about the partnerships. Oral presentations in a "poster session format" gave the undergraduates an environment in which they could learn and experience how to put their thoughts and reasoning into words. The presentations gave the entire program closure, and gave the undergraduates a chance to practice presenting their research documentation to a live and interested audience.

Surveys

When the ten weeks were over, a survey was developed by the electrical engineering student/faculty partnership and was handed out to the other nine undergraduates and faculty who participated in the Research on Research program. The students were asked four questions about their experience. Analysis of the survey results provides on overall perspective from the other participants and serves to contextualize the electrical engineering faculty/student partnership approach.

The first question asked what the students would change to improve their experience. *"If I could change/improve the experience I would spend a lot more time in the lab,"* said one student. Another student responded *"I was overall happy with my experience; however, I wish my faculty partner had space at the time to let me do more laboratory experimentation."* Another student commented on his working relationship with his faculty member, *"The autonomy was nice, however, I may have learned more of the "unwritten" rules of research had I worked more closely with my prof."* These survey results illustrate the importance of a laboratory component in this type of internship program.

The second question gauged the other students' appreciation for the ePortfolio. The participants' ratings, shown in Figure 5 indicate that the ePortfolios were well appreciated. One student commented, "*I would rate that the multimedia aspect was a 10 - I believe 10 would be the highest. This multimedia project allowed me to connect the three different labs involved in the research. This project was critical in that it allowed the lab members to connect in a new way, facilitating exchange of information and allowing us to create a more efficient research environment. It was educational for all of the staff and faculty at the three labs and they all benefited from and continue to still use the site to exchange information and increase awareness of post transplant skin cancer."* And another student responded, "*The multimedia aspect was a great way to make it more interesting for the professor. It opened up new avenues to display their research."* Overall, the responses about the multimedia ePortfolios indicate a positive appreciation from the other students, which is similar to the response from the electrical engineering faculty/student partnership.

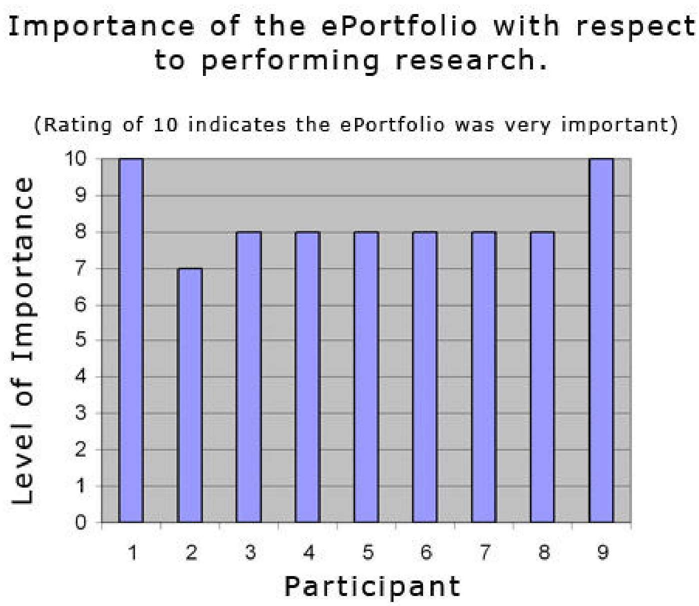

Figure 5 - Participant ratings of the multimedia aspect which included the ePortfolio.

The third question asked the participants what they considered unique about their partnership's individual research methodology. One student said, "*I was able to work closely with a Ph. D student and learn from him what the research process was really like, as a student going through it himself."* Another student responded, *"I think the most unique thing that I did was to come into the lab, run a session, then interview participants afterward. Instead of having someone tell me what the research was, or explain parts of it to me, I lived the process from start to finish."* These two responses show that the participants found graduate student interaction, and autonomous laboratory testing to be very valuable experiences.

The fourth question asked the students if they found any unexpected or new information about graduate school through their summer internship. The participants overwhelmingly responded as one student did, *"I really didn't learn much more about graduate school than I already knew."* Participant after participant responded in this way, showing that the participants did not feel that the summer internship provided them with any new insights into graduate school. This was very different from the response from the electrical engineering undergraduate, illustrating that the electrical engineering approach was successful in providing a glimpse into the graduate school experience.

Finally, the faculty members were asked how they benefited from the "Research on Research" program. One faculty member in chemistry said that the program gave him a chance to interact with faculty members from throughout the university. He is now collaborating with the professor from electrical engineering on a joint research project in the area of bionano-technology. In addition, two partnerships have published their summer research in academic journals. Another two partnerships have had conference papers accepted for presentation at international conferences. Two of the undergraduates have been accepted into graduate school and will be working with their faculty members and continuing their research.

Conclusion

In conclusion, a means by which electrical engineering research can be effectively extended to undergraduate students via a university-wide multi-media technology internship program is described. The electrical engineering faculty/student partnership focused on a small scale research project that exhibited primary aspects of graduate level research. This included four phases: (1) design, (2) simulation, (3) fabrication, and (4) test.

After this summer experience, the electrical engineering faculty professor and undergraduate student partnership were invited to give an IEEE seminar where the audience was comprised of a large number of undergraduates. The multimedia ePortfolio was used as the presentation visual aid. The presentation was well received by the freshman and sophomore electrical engineering students.

To increase the effectiveness of the Research on Research program, it would be helpful for the participants to be given a template for their ePortfolio. This allows less time to be spent designing the structure of the ePortfolio and more time to be spent with their faculty professor and research. A general template might be introduced to the students at the start of the program.

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