Growing a Culture of Intellectual Inquiry in Engineering Education and Research

Elisabeth McGrath
Center for Innovation in Engineering & Science Education
Stevens Institute of Technology, Hoboken, New Jersey 07030, USA
Elisabeth.McGrath@steven.edu

Keith Sheppard[1]

Abstract - **An initiative was developed as a collaborative effort within the School of Engineering and the institution's K-12 outreach center to promote a culture of inquiry in engineering education among all faculty; to engage faculty in exploring research-based instructional strategies; to encourage faculty to examine their own instructional practice and adapt appropriate strategies for their own classrooms; and to build capacity for engagement in methodologically-sound engineering education research. Strategies to build this learning community have included: seminars and workshops by renowned engineering educators and STEM learning research experts; "brown bag" lunches facilitating faculty discussions around issues of teaching and learning; a competitive internal grant program for faculty to redesign a course and assess learning outcomes; assistance with identification and development of education research grants; access to and consultation by education researchers; and providing recognition, travel stipends, and other incentives for faculty engaged in engineering education research. Preliminary results show growth in the number of faculty engaged in education research, both as adaptors of effective practice, and as creators of new knowledge, as measured by participation in seminars and events sponsored under the initiative; number of papers presented at engineering education conferences; affiliations with engineering education organizations and collaborators; and number of education research proposals submitted and awarded. Impact has been noted both among veteran faculty as well as new faculty.**

Index Terms – culture change, engineering education research, effective teaching practices, faculty engagement.

INTRODUCTION

Traditional incentives at research-intensive engineering institutions reward faculty for disciplinary research activity and publishing. Faculty engagement in engineering education research, and the processes related to awareness and adaptation of effective pedagogical practices to improve student learning are, in many institutions, a distant second—and often competing—priority for faculty time and attention.

In order to promote a culture within the School of Engineering that fosters and recognizes faculty engagement in engineering education research and the adaptation of such research and other documented, research-based, pedagogical best practices to their teaching, an initiative has been developed known as Research and Innovation in Engineering Education (RIEE). This initiative has been envisioned as a multi-dimensional culture change effort aimed at: increasing awareness among faculty of the state of the art in engineering education research; improving teaching practice; identifying and growing the Institute's distinctive strengths in engineering education; and increasing collaborations with K-12 schools and community colleges for the benefit of the Institute and the partners; and increasing engineering education research funding.

The RIEE effort was catalyzed by collaboration between the School of Engineering and the Institute's K-12 outreach center known as the Center for Innovation in Engineering and Science Education (CIESE). The Center's mission had in 2004 been expanded to include undergraduate education after more than 15 years as a national leader in developing innovative programs to enhance K-12 mathematics and science education.

CULTURE CHANGE IN ENGINEERING EDUCATION

It has been well recognized that in order to effect sustainable change in engineering education the culture of the organization is a key factor. Godfrey [1,2] has discussed the increasing awareness of the role of culture as engineering education reform has taken hold in recent times on an international scale. She points to a disconnect between on one side the calls for cultural change made by professional bodies and government and on the other side the level of understanding by engineering educators and their change leaders of how culture impacts behaviors and practices that will enable such reform. She has built upon the scholarship of how organizational culture influences change to develop a framework applicable to engineering education.

This framework identifies a number of core cultural dimensions of beliefs and assumptions and it is at this level that shifts must ultimately occur to support sustained cultural change. The beliefs and assumptions derive from values and norms which in turn are manifested in artifacts (such as mission statements, documents, websites, curricula, buildings, etc.) and in practices and behaviors. Godfrey points out that change via strategic planning is typically

[1] Keith Sheppard, Associate Dean of Engineering, Keith.Sheppard@stevens.edu

driven from the level of identifying desired values and norms. Successful cultural change can be achieved only when these lead to changed artifacts, practices and behaviors at an operational level that, once sustained, become embodied in the cultural norms and assumptions of the organization.

Further evidence for the significance of cultural analysis in guiding successful change has come from research associated with common curricula restructuring activities at partner institutions of several of the engineering education coalitions sponsored by the National Science Foundation (NSF). These include Merton et al. [3] with the Foundation Coalition. They have highlighted the issues associated with achieving scale up following success with early adopters. Gateway Coalition research has shown how both quantitative and qualitative measures can help assess and support programs of curricula change both in terms of program effectiveness and culture change [4]. Researchers with the Greenfield Coalition for New Manufacturing Engineering partnered faculty members with anthropologists who used ethnographic methods to document culture change and in so doing informed change leaders on the appropriateness and impact of their strategies [5].

THE CULTURAL CONTEXT AT STEVENS

The culture at Stevens Institute is one of a small technological university with 131 regular faculty members plus a significant number of full-time special faculty, many of whom have significant industrial experience and are dedicated to teaching, 1800 undergraduates and 3000 graduate students, many part-time. This close-knit community promotes good faculty-student and faculty-faculty interactions. The Institute has prided itself in offering a broad-based undergraduate engineering education since its founding in 1870. It has stayed true to this core philosophy, (which carries with it for students the challenge of a heavy credit load), through the national trends to more narrowly defined disciplinary programs and reduced credit requirements for the bachelor's degree. The Stevens engineering curriculum has a large core of engineering courses in addition to those in mathematics, science, engineering management and humanities/social sciences.

There are programs in eleven engineering disciplines offered by five departments. Faculty ownership and oversight of the curriculum is through faculty committees responsible for each program, each of which is represented by the program committee chair on the School of Engineering curriculum committee.

In spite of this conservative stance on the broad-based nature of the engineering degree, the faculty have been innovators in course and program design and delivery. For example, Stevens was on the leading edge of the national move to incorporate more and earlier design into the curriculum with the result that there is a design course in each semester. It was also the first to require undergraduates to own a personal computer for use in coursework. Teaching has always been an important part of all regular faculty members' activity.

Although significant value is placed on delivering a high quality undergraduate education at Stevens, the prevalent culture has been one that has emphasized disciplinary research among the faculty. In fact the level of disciplinary research has increased substantially in recent years as measured by the usual metrics in response to the Institute's strategic plan.

There has been relatively little experience in engineering education research. The Institute has not had the benefit in this respect of the presence of an education department and associated education research faculty. Yet, it has been recognized that alignment with the national movement to research-based engineering education innovation is important to the Institute's commitment to excellence in undergraduate education.

To shift the culture to one which promotes engineering education research required a recognition of the above cultural context and from that to build a strategy that included a process for awareness building and the provision of inducements such that faculty would investigate and experiment with engineering education research pilot initiatives and research-based, pedagogical methods. The awareness building was deliberately staged such that faculty would be motivated to seek out the relevant education research in their area of interest rather than have a process that might have made the task of engaging in education research appear daunting for a newcomer facing the large body of knowledge associated with engineering education research.

As previously mentioned, having the CIESE organization join the School of Engineering was the catalyst that helped promote development of the strategy that became the RIEE Program to instill a new direction in engineering education research.

THE RIEE PROGRAM

A key to the development of the RIEE initiative was its early advocacy and promotion by the Dean of Engineering to departmental leadership and faculty, including its inclusion as part of strategic planning retreats and reports. This has also included enhanced emphasis on educational and outreach activities in faculty activity reporting and associated recognition and rewards. These reflect the research on culture change previously highlighted which points to the significance of change leaders establishing the desired values and from these the associated practices and behaviors at the operational level. Breaking out educational research explicitly in faculty activity reporting and therefore performance evaluation and reward was judged a significant step toward motivating behaviors and from these building norms in line with the desired culture change.

The RIEE initiative has involved a number of complementary elements. Preceding formal programming, a six-month planning effort was undertaken, involving representatives of all the engineering departments, including faculty and department heads, and leadership from the School of Engineering and the CIESE. During this time, a self-assessment was undertaken to identify interest, topical areas for educational research initiatives, and potential funding opportunities. An orientation and awareness-building effort was initiated to acquaint leadership and interested faculty in educational research opportunities through funding agencies such as the National Science Foundation and the Fund for Improvement of Post-Secondary Education and the expectations, requirements, and methodologies used in engineering education research. Again this awareness building was directly reflective of the research on culture change.

Based on the level of interest and participation of faculty and several tangible outcomes of this preliminary effort, which included the submission of several education research proposals and partnership in a major national curriculum reform project sponsored by NSF, the RIEE program was expanded.

The scope of the RIEE activities has been such that in addition to a focus on improved engineering education in the Institute's undergraduate programs there has been a concern with issues of enhancing the pipeline of female and other underrepresented groups in engineering. The programs have also sought linkages with community colleges and with the K-12 community. These latter constituencies have much to offer in collaborative educational research and pedagogy improvement.

SEMINAR SERIES

The first component of the RIEE program was establishment of a seminar series which sponsored seminars by leading authorities in engineering education and also speakers who could enlighten the faculty about research into learning, particularly within STEM fields. This series was launched with a well-publicized and well-attended event featuring an internationally-known educational researcher and author who had recently published a book on excellence in college-level teaching.

Seminars have been typically conducted as lunch events, with lunch provided, to facilitate participation by busy faculty members. Seminars have been well attended by faculty the School of Engineering as well as those from science and from technology management programs who were interested in improved teaching and learning, particularly at the undergraduate level. These events have included a mix of faculty, from young to veteran, research active and not.

Among the seminars held were:

- Senior Advisor, National Science Foundation, Directorate of Engineering: Engineering education programs and proposal guidance
- ASEE National Teaching Award Recipient: Inductive teaching
- Engineering Dean – Georgia Tech: Will ABET EC2000 make engineering more female friendly?
- Mechanical Engineering Department Head – Johns Hopkins University: Curriculum redesign to encourage diversity in engineering
- Director of Center for the Advancement of Scholarship on Engineering Education of the National Academy of Engineering: CASEE mission and how to become involved
- President of Olin College of Engineering: Elements of engineering education for a flat world economy

WORKSHOPS

Complementing the seminar series have been several workshops in which some of the Institute's most effective teachers, as well as outside guests, have led interactive discussions on implementing best teaching practices. Cooperative learning modes, use of technology, and increasing interactivity have been three areas of emphasis of these workshops. For example, one of our own faculty members is a certified trainer of the American Society of Civil Engineers ExCEED program for effective teaching [6]. This faculty member, an acknowledged effective teacher, presented the workshop to a range of faculty as an RIEE-sponsored event. As with the seminars featuring external speakers, a broad-based participation was achieved.

In another workshop, a junior faculty member with experience in the use of technology in the classroom presented a thought-provoking workshop on how technology, such as interactive tutorials and web-based resources, engage today's students.

In addition, the distinguished author and educator mentioned above returned to campus to provide a workshop to reinforce the techniques that he had first discussed as the inaugural seminar series speaker.

INTERNAL SEEDING OF EDUCATIONAL RESEARCH

An exciting and significantly enabling component of RIEE has been an internal catalyst grant program for STEM educational research and innovation. The rationale for this program was not only to fund a variety of educational research proposals that would be piloted within the Institute, but also, by providing visibility and summer support for faculty, to entice a greater number faculty to become familiar with engineering education research literature—needed for their proposals—and methods. Funding for this effort came from an allocation from the State.

A series of technical assistance sessions to promote the catalyst grant program drew approximately 70 faculty members, representing approximately 60% of the tenured and tenure-track faculty involved in educating engineering students through engineering topics or science and mathematics courses. Applicants represented both veteran as well as junior faculty. A letter of intent, signed by the faculty member's department head, was required, along with a proposal that identified outcomes, potential impact, timeline, and deliverables. The grant solicitation deliberately emphasized programs that impacted engineering students in their first two-years of undergraduate education.

Thirty-one letters of intent were submitted, and a preliminary review was made by an internal panel to encourage or discourage the submission of a full proposal. Seventeen full proposals were received and 11 awards were made, with grants ranging from $17,000 for a single investigator to $40,000 for a multi-disciplinary team project. Funding was used to purchase equipment, such as remote response technologies, called "clickers," to improve interactivity in large lecture classes; to provide support for faculty and graduate student summer work devoted to curriculum development; and for program dissemination.

One project of note was a collaborative effort by a team from mathematics, physics and engineering. They undertook the development of integrated modules that could be utilized by professors in all three fields in their early core classes to assist in the teaching of the mathematics and science in the context of their application in engineering. In so doing they addressed a perennial challenge that can have broad impact in engagement, learning and retention.

All proposals were required to provide assessment and dissemination plans. The former have been supported by funding for an external expert in educational assessment who provided advice to faculty during the proposal writing phase and following award of the successful projects.

Funded projects included:

TABLE I

Enhancing Student Understanding, Engagement and Motivation in Sophomore Fluid Mechanics through the Introduction of Computational Fluid Dynamics Software Tools
Multimedia Learning Environments for Virtual Experiential Engineering and Incorporation into the Undergraduate Curriculum
Self-Directed Software Engineering Learning Modules for Engineering Education
Enhanced Integration of Mathematics and Physics into the Engineering Curriculum
Revision of the Engineering Core Course E-243, Probability and Statistics for Engineers
Assessment Performance Criteria-Based Monitoring of Teaching Effectiveness
Revision of Engineering Graphics to Support an Evolving Core Design Sequence
An Introductory-Level Course in Quantitative Biology for Engineers
Novel Analytical Chemistry Laboratory Experiments for Improving Skills of Engineering and Chemical Biology Undergraduates
Total Design: Integrating Systems Engineering and a Systems Perspective in Required Freshman Design Courses
Active Learning Through Technology (ALERT!): Modern Physics

A requirement of the catalyst grants and of the funding from the State that supported this program was the dissemination of educational products to several of the state's community colleges. Several meetings involving faculty awarded catalyst grants with faculty at neighboring community colleges have taken place, with the objective of sharing materials, methods, and lessons learned and to increase opportunities for transfer and articulation between the two-year colleges and the Institute.

Similarly, several of the catalyst grants and RIEE collaborations have spawned other programs that have resulted in major K-12 initiatives. One such collaboration has been developed into a three-year National Science Foundation award to promote engineering in middle and high schools through the use of information technology and LEGO [7].

RESULTS OF RIEE FUNDED PROJECTS

In order to illustrate the impact of the RIEE efforts to promote engineering education research, several projects are highlighted here.

Revision of Engineering Graphics to Support an Evolving Core Design Sequence

This project was directed to a freshman engineering graphics course taken by all entering engineering students. While there were a number of goals to the project, a key one was to investigate the proposition that student engagement could be increased by a change in the format, especially in the second half of the course, from a rigid syllabus of teaching graphics elements with associated exercises, to one that was project-based and allowed the students to use a contemporary object of interest to them as the foundation to a more self-directed exploration of the capabilities of the graphics software tool (SolidWorks), especially using more advanced features to produce complex geometries.

The study was conducted with one faculty member in three pilot sections out of a total of ten sections taking the course, with the other seven taking the regular syllabus. The course outcomes for all sections were kept the same. The results, based on a survey of student engagement, showed that indeed the revised project-based second half led to a statistically meaningful improvement.

From a cultural perspective the real value of this study (which was subsequently published [8]) was that the three faculty members teaching the non-pilot sections had been skeptical of the merits of the new approach as they were concerned about "covering the material". The results of the study convinced them to adopt the project-based approach in the following year and an interview conducted with them found them to be very happy with the results.

Active Learning Through Technology (ALERT!): Modern Physics

A faculty member who had been teaching modern physics for many years to engineering students was supported by RIEE to explore active learning in a large lecture section format mediated by a wireless classroom response system that utilized the students' laptop computers in conjunction with a tablet PC controlled by the faculty member. The proposition of the study, based on the results of previous published research at other institutions in a different context, was that the response system would allow greater participation by the students who tended to be passive in the large class and to allow the faculty member to explore in real time the students' understanding of concepts (pre-concepts) that he was aware perennially caused difficulty.

The study compared results from two semesters before using the technology with three semesters using it thus it evaluated 233 pre-project students and 298 project students. The conclusion was that the technology made it possible to increase conceptual understanding while making a small improvement in grades. The best students did significantly better. Classroom participation was 100%. The most beneficial outcome provided by the technology was the in-class information about student misconceptions, making it possible to improve the teaching.

The study has raised additional questions concerning the influence on attendance and the balance of lecture time versus time spent interacting on concepts. The results have been shared internally through the RIEE seminar series with other faculty members teaching large classes and other efforts have been spawned to use interactive technologies to aid active learning. The study has been published [9-10].

Enhancing Student Understanding, Engagement and Motivation in Sophomore Fluid Mechanics Computational Fluid Dynamics Software Tools

A chemical engineering faculty member who is very active in disciplinary research had attended the RIEE seminar series and this provided the stimulus for him to propose an RIEE funded study to determine if the use of computational experiences could improve learning by enabling students to confront and correct their misconceptions in a sophomore fluid mechanics course taken by chemical engineering majors. The project had two major components; the first was to use a Fluid Mechanics Concept Inventory to uncover student misconceptions. The concept inventory was a modification of one developed from engineering education research funded by the National Science Foundation [11]. The second component was to use FlowLab software to allow students to discover that incorrect models fail and replace them with correct ones.

The research demonstrated over 60% improvement in overall understanding of the tested concepts by this approach. The research also provided questions for future study, including the role of different teaching methods to address specific issues, correlation of concept inventory performance to various learning metrics not evaluated in the first project and also research into improving the concept inventory itself.

This project represents a key aspect of the culture change that is emerging, with a research active faculty member who had not previously engaged in engineering education research now doing so, both as an activity of intrinsic interest, building his study on published research findings, and also as a means to directly improve his course.

Enhanced Integration of Mathematics and Physics into the Engineering Curriculum

This project was the most challenging and most fundamentally influenced by culture. The goal was to improve the integration of early mathematics, physics (mechanics) and engineering (mechanics of solids) such that students recognized the connections and to enhance engagement and learning in the mathematics and physics by enabling students to explore their relevance to engineering.

The project partnered three faculty members teaching these subjects to Freshmen and Sophomores. The project started with the three faculty members together with the Associate Dean of Engineering (one of this paper's authors) holding meetings to discuss the challenges and the education research literature on past efforts to achieve integration – many of which had not been sustainable. Key to these discussions was the recognition of the cultural differences between the disciplines and the faculty values and norms that influenced how they taught their subjects. The discussions revealed a significant difference in terminology and notation being used, especially between mathematics and engineering courses and this was, therefore a source of potential problems with integration.

The strategy that evolved was to acknowledge these cultural differences and to use modules as the integration points – with the modules providing engineering challenges that could be addressed in all three courses. In this way the individual subjects could be taught in large part in the manner that the faculty believed they should be from their discipline's culture in order to maintain their integrity.

A number of modules were developed and implemented by the three faculty members. The preliminary assessment suggested that these modules were not sufficiently engaging to the students for these to achieve the desired impact. Further systematic study is planned. Topics for investigation that were identified from the preliminary study include a more detailed investigation of the key topics and concepts that are central to connecting the mathematics to engineering, including the use of concept inventories, and those in mathematics and physics that have significance for retention in an engineering education.

IMPACT ON EXTERNAL FUNDING OF EDUCATIONAL RESEARCH

A tangible outcome of RIEE beyond the involvement of faculty in seminars and workshops as well as internally seeded educational research, especially from the latter, has been a significant expansion in proposal submissions for external support of educational research and innovation. Regular faculty (outside of research center activities) from the School of Engineering submitted 13 such competitive proposals in the 2002-03 academic year (prior to RIEE) and had 4 proposal funded that year. In the 2005-06 academic year, there were 31 proposals submitted and 7 proposals funded, representing increases of 140% and 75% respectively.

The proposals have included submissions to various National Science Foundation programs that support engineering education research and innovation, such as Department-level Reform (DLR), Course-Curriculum-Laboratory Innovation (CCLI), Partners for Innovation (PFI), Science, Technology & Engineering (STEP), also the U.S. Department of Education's FIPSE Program.

Areas of focus have included several proposals aimed at improving the engagement and persistence of women and minorities in engineering as well as increasing the pipeline of these under-represented groups through partnership with community colleges. Others have included K-12 outreach contributions. Several proposals have been a direct outcome of the internal RIEE catalyst grant program.

IMPACT ON PROFESSIONAL ACTIVITIES

A further tangible outcome of RIEE has been a dramatic increase in participation of faculty in engineering education conferences and associated presentations and publications. For example at the 2006 ASEE Annual Conference there were 13 faculty members attending and 14 papers presented. This compares to typical numbers around 5 only a few years prior. For a research-oriented School of Engineering with approximately 60 regular faculty members, this is significant.

Faculty engagement has been further facilitated by the Dean of Engineering's commitment to support faculty membership of the American Society for Engineering Education (ASEE). New members have been enrolled through the ASEE Deans Program and renewals supported through the Dean's Office. This resulted in an ASEE Campus Representatives award in 2005 in large part due to increased enrollment of members. Having a majority of the faculty regularly receiving ASEE engineering education journals provides current awareness of issues in engineering education and knowledge of best practices and research. Such awareness was limited to very few faculty members in the past. This is another example of a practice, implemented by change leadership, to influence behavior and hence culture change.

ELECTRONIC RESOURCES

A dedicated website was created for the RIEE initiative (http://riee.stevens.edu). It provides a repository of past presentations, funding resources, links to education organizations, pertinent education articles and journals. An events calendar is included as well as articles and links describing best practices in engineering education. Articles and links to websites on national issues are included, such as those of Women and Minorities in Engineering and other issues of the pipeline to engineering careers. Also accessed are national policies and reports of bodies such as the National Academy of Engineering and CASEE.

An electronic listserv was established to provide interested faculty with information and a point of connection on educational grant opportunities.

CONCLUSIONS

The RIEE initiative, with its various complementary elements, was introduced to affect a culture of inquiry in engineering education among the faculty. This was built upon recognition of the role of extant culture on change processes and the strategies were tailored to that understanding. The goals were to engage faculty in exploring research-based instructional strategies; to encourage faculty to examine their own instructional practice and adapt appropriate strategies for their own classrooms; and to build capacity for engagement in methodologically-sound engineering education research. The results show growth in the number of faculty engaged in education research, both as adaptors of effective practice, and as creators of new knowledge, as measured by participation in seminars and events sponsored under the initiative; number of papers presented at engineering education conferences; affiliations with engineering education organizations and collaborators; and number of education research proposals submitted and awarded. Impact has been noted both among veteran faculty as well as new faculty.

ACKNOWLEDGMENT

Dean George Korfiatis (now Provost) is acknowledged for advocacy and support. The financial support is acknowledged of the State of New Jersey. Support for some of the work described has been provided by NSF ITEST grant award number: ESI-0624709

REFERENCES

[1] Godfrey, E, "Defining Culture: The way we do things round here", *Proceedings of the American Society for Engineering Education Annual Conference*, 2001, Session 3630.

[2] Godfrey, E, "A Theoretical Model of the Engineering Education Culture: A Tool for Change", *Proceedings of the American Society for Engineering Education Annual Conference*, 2003, Session 2630.

[3] Merton, P, Froyd J, Clark, M and Richardson, J, "Challenging the Norm in Engineering Education: Understanding Organizational Culture and Curricular Change", *Proceedings of the American Society for Engineering Education Annual Conference*, 2004, Session 2630

[4] Fromm, E and McGourty, J, "Measuring Culture Change in Engineering Education", *Proceedings of the American Society for Engineering Education Annual Conference*, 2001, Session 3530.

[5] Baba, M, and Pawlowski, D, "Creating Culture Change: An Ethnographic Approach to Transformation of Engineering Education", *International Conference on Engineering Education*, Aug. 6-10, 2001, Oslo, Norway, Session 7E3-5.

[6] Estes, A,C, Welch, R, W, & Ressler, S, J, "Teaching Lessons Learned: The ExCEED Teaching Model", *J. Profl. Issues in Engrg. Educ. and Pract*., Volume 131, No. 4, Oct. 2005, pp. 218-222.

[7] Stolkin, R, Hotaling, L, Sheryll, R, Sheppard, K, Chassapis, C, McGrath, E, "A paradigm for vertically integrated curriculum innovation – how curricula were developed for undergraduate, middle and high school students using underwater robotics" *International Conference on Engineering Education – ICEE2007*, September 3-7, 2007, Coimbra, Portugal, Paper 355.

[8] Nastasi, J, Sheppard, K, and Chassapis, C, "Revision of Engineering Graphics to Support an Evolving Core Design Sequence", *Proceedings of the American Society for Engineering Education Annual Conference*, 2006, Session 2165.

[9] Rothberg, G, "Active Learning through Technology (ALERT): Modern Physics", *Proceedings of the American Society for Engineering Education Annual Conference*, 2006, Paper 1215.

[10] Rothberg, G, "Active Learning through Technology (ALERT): Modern Physics; An Update", *Proceedings of the American Society for Engineering Education Annual Conference*, 2007, Paper 1945.

[11] Martin, J, Mitchell, J, Newell, T, "Work in Progress: Analysis of Reliability of the Fluid Mechanics Concept Inventory", *Proceedings of the 34th ASEE/IEEE Frontiers in Education Conference*, Oct 20-23, Savannah, Georgia, Session F1F.