

# Engineering-Education Collaboration – Virginia Tech

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**Abstract** – This paper presents a summary of collaborative activities between engineering and education faculty members targeted at improving engineering pedagogy at Virginia Tech. The activities began in 2003 with a planning grant from the NSF. A new Masters/Licensure program has been developed for engineering graduates. This program is expected to train technology/engineering educators for k-12 instruction. A number of data collection and analysis activities have been initiated for analyzing curricular changes beginning with the freshman engineering program. Use of electronic portfolio in engineering instruction is being explored. The interdisciplinary group has developed a number of research proposals for expanding the scope of studies that are currently under progress. The group has recently received informal approval of a large engineering education research grant from the NSF. This grant is targeted at reformulating the freshman engineering and bioprocess engineering programs using the concept of spiral curriculum.

**Index terms** – Engineering assessment, Electronic portfolio, Freshman engineering, Pedagogy, Spiral curriculum

## BACKGROUND

Virginia Tech's College of Engineering (COE) is the sixth largest US engineering program in terms of bachelor's degrees awarded in 2002 [1]. All engineering freshmen at Virginia Tech follow a common General Engineering (GE) curriculum in first year and are assigned to the Department of Engineering Education (EngE) (former name Division of Engineering Fundamentals). The formal announcement of the creation of EngE department was made in May 2004 although activities in this direction started with the joining of COE Dean Aref in April 2003. Students transfer from EngE department to one of eleven degree-granting departments as sophomores. Two major changes occurred in the COE after Dean Aref took over in April 2003: i) Computer Science (CS) Department became part of COE and ii) More emphasis was placed on engineering education research activities in the College.

With the addition of Computer Science, the educational objectives of the common first year GE program are undergoing major changes. Alice ([www.alice.org](http://www.alice.org)), an object oriented programming language that is used in introductory computer science courses at some schools, is replacing Matlab programming language in first introductory engineering course starting fall 2004. The second semester engineering course that focuses on engineering design is being revised and for the first time two versions of this design course, namely, a digital version (for computer science, electrical and computer engineering students) and a non-digital version (for civil, mechanical, chemical, etc. majors) will be offered in spring 2005. In order to address the need for increased emphasis on engineering education research activities the COE's new leadership, in consultation with engineering faculty and administrators, has re-conceptualized and updated the mission of the EngE department. This new EngE department is now not only responsible for conducting the freshman GE curriculum, but is also responsible for improving engineering pedagogy within the College. The three key issues that the College and EngE must address are: i) the need for faculty and administrators to better understand the teaching and learning process so that they will be willing and enthusiastic partners in change, ii) the fact that the existing engineering curriculum does not fully meet contemporary standards as suggested by several decades of progress in understanding student learning and development, and iii) the culture for assessment within COE is poorly developed and lacks an explicit focus on learning. In order to address

these issues the EngE faculty is expected to undertake collaborative studies with their counterparts in other engineering and education departments. This paper presents current status of such collaborative activities that primarily began in the summer of 2003.

## **BRIDGES FOR ENGINEERING EDUCATION – VIRGINIA TECH (BEEVT)**

In Spring 2003, the National Science Foundation (NSF) published a solicitation for their “Bridges for Engineering Education” program. This presented a perfect opportunity to EngE faculty to collaborate with colleagues in the School of Education in developing a proposal to initiate engineering education scholarly activities. Since NSF’s intent with the “Bridges” solicitation was, in part, to improve engineering pedagogy, we used this opportunity to initiate this new collaboration among the faculty in Engineering Education, Technology Education, and Educational Psychology to build an interdisciplinary proposal writing team. We quickly became acquainted and worked closely together on the proposal for the next couple of months. In September 2003, NSF awarded a planning grant, namely, Bridges for Engineering Education-Virginia Tech (BEEVT) to this interdisciplinary group and thus began the first NSF supported engineering education research project involving EngE faculty at Virginia Tech.

The goal of BEEVT is to initiate long-lasting collaborative relationships among Virginia Tech Engineering and Education faculty, K-12 educators, corporations, and policy/decision makers throughout Virginia. The specific objectives are to: i) develop a new Masters Technology Education Teaching Licensure Option for engineering graduates, ii) create a contemporary framework for undergraduate engineering pedagogy, beginning with freshman engineering experiences, and iii) initiate the “Virginia Engineering /Education Collaborative” to ensure stakeholders’ ownership of project outcomes.

The project work began in fall 2003 and a number of initiatives have been undertaken to meet the objectives of the project. A brief description of progress made to date is given below.

### **Masters/Licensure Program**

In order to develop the proposed Masters/Licensure program, a “Technology Education Masters/ Licensure Program” (TEMLP) sub-committee, consisting of four faculty members (two engineering, one technology education and one educational psychology), met several times in fall 2003 and spring 2004 under the leadership of the technology education faculty. The group has designed a new Technology Education Masters / Licensure Program (TEMLP) for engineering graduates. This may be the first graduate program designed specifically for licensing *engineering graduates* in Technology Education. Because of the large number of VT engineering graduates and the tremendous demand for Technology Education teachers in grades 6-12, we are optimistic about our potential to recruit a substantial number of engineering students in coming years for this new TEMLP. It’s a 15-month program with following coursework:

- 18 hours of Technology Education (TE) courses (a mix of courses that introduces them to Technology Education’s culture, content, and pedagogy);
- 18 hours of education/pedagogy/research (Curriculum, Methods, Educational Psychology, Social Foundations of Education, Content Area Reading, Educational Research);
- Student Teaching (300 Hours) and Clinical Experiences; and
- An option for Engineering Education electives.

Our intent is to create some clinical experiences in the GE courses for those TEMLP students who hold engineering degrees. Their clinical experiences will also include experiences in middle and high school Technology Education programs. Technology Education (TE) Licensure in Virginia requires passing scores on the Praxis I and II exams. The TE Praxis II is a “subject assessment” that tests teacher candidates’ general knowledge of TE content. In order to get a better understanding of how engineering graduates might perform on the TE Praxis II exam *before* taking any TE masters/licensure coursework, the TEMLP subcommittee invited VT engineering seniors to volunteer to take the Praxis II in January 2004. We offered to subsidize the cost of the exam and pay each volunteer a small stipend for his or her time. We selected five from among the 26 who volunteered, each majoring in a different Engineering department: Electrical Engineering, Mechanical Engineering, Industrial Systems Engineering, Computer Engineering, and Aerospace Engineering. All five seniors passed the Praxis II test, suggesting their engineering degree provides an excellent foundation for a career in the field of technology education. Although it is a too small a sample to draw broad conclusions, our findings suggest that VT engineering graduates enrolled in the TEMLP will not have difficulty passing the Praxis II exam [2]. Though we were not able to advertise this new TEMLP until April 2004, we did recruit 5 students to enroll in the program, which began in Summer 2004.

## Contemporary Framework for Undergraduate Engineering Pedagogy

A group of EngE faculty met with a faculty member from Education Psychology on a regular basis during fall 2003 and spring 2004 to initiate various activities leading to development of the proposed contemporary curriculum framework. These initiatives can be classified into following categories:

- Collection and analysis of data
- Development of a continual assessment scheme
- Development of proposals for implementing activities planned in BEEVT

### Collection and Analysis of Data

The EngE department offers two introductory engineering courses, namely, “Engineering Exploration,” and “Engineering Graphics” in the GE program. In addition to introducing some fundamentals of engineering, these courses are designed to prepare GE students for their subsequent studies and are considered as the service courses in various engineering departments. The College of Engineering has 11 degree-granting departments that offer 13 different majors and these courses are expected to satisfy their diverse needs. The design of these introductory engineering courses that can meet the needs of all engineering departments is obviously a challenging task and hence these courses undergo frequent changes. The most obvious change during last five years in the ‘Engineering Exploration’ course is perhaps the dramatic decrease in theory and problems (i.e., traditional engineering topics such as statics, material balance, and electrical theory) and a corresponding increase in engineering design and hands-on activities. Details of changes are given in [3].

In the past, due to lack of collaboration between faculty members in EngE and other engineering departments, the EngE faculty primarily designed the GE courses. However, with the new mission of the EngE department, it's important that EngE faculty develop meaningful collaborative activities with their counterparts in various engineering departments. One of the areas of collaboration is in designing the GE courses. Traditionally this was accomplished in a sporadic and ad-hoc manner that produced acceptable but certainly not optimal results. In order to streamline the process of receiving feedback from faculty members from various engineering departments regarding contents of freshman year engineering courses, a web-based tool has been developed that allows systematic collection, processing, and storage of feedback data. A brief description follows.

#### Online Course Feedback Tool

A web-based departmental feedback system, targeted at receiving systematic and regular feedback from the degree-granting departments regarding the contents of the first three semesters of engineering courses, has been developed. This system allows a user to design freshman and first semester sophomore engineering courses by choosing topics (programming, communications, ethics, CAD, graphing, design, profession, and problem solving) from an available set and allocate them to one of 42 weeks comprising the first year and a half of the students' education. Figure 1 shows an example of such feedback. In this example, the user has selected problem-solving to be taught two weeks in each of the first three semesters, the engineering profession to be covered during two weeks of the first two semesters, and so on. The center of the circle allows the user to input his/her expectations of an incoming freshman. While each of the three rings represents a semester, there is no time significance of the order of placement within a given ring; the software is designed to fill the rings, clockwise from north, with problem-solving first, profession second, etc. This is to facilitate visual comparisons.

When the user has completed the graphical portion a summary page, the visual information is automatically translated into quantitative information in a tabular form and allows the user to go back and make comments before submitting. Once submitted, the input data is stored and readily available for statistical analysis and re-creation of the graphical input. A group of BEEVT investigators held a meeting with various Assistant Department Heads in fall 2003 and explained the purpose and operation of this feedback tool, which is now available to entire COE faculty through BEEVT web site ([www.beevt.eng.vt.edu](http://www.beevt.eng.vt.edu)). All faculty members have been requested to use this online tool to give their feedback. An example feedback from a faculty in aerospace and ocean engineering (AOE) department is shown in Figure 2.

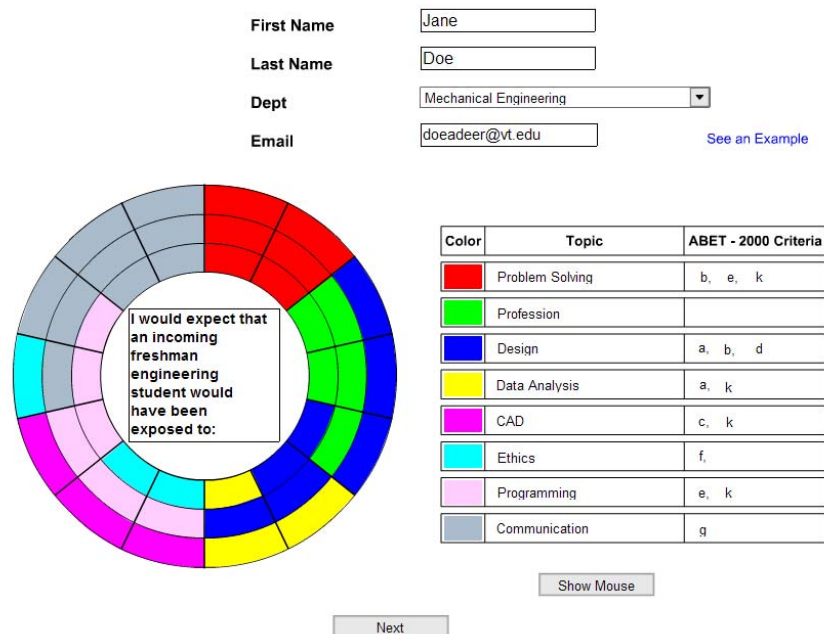


FIGURE 1  
WEB-BASED DEPARTMENTAL FEEDBACK SYSTEM

#### Analysis of Retention and Other Data for Engineering Cohorts and BEEVT Web Site

At Virginia Tech, students' GPA, retention, graduation, and intra-college migration data are maintained online by the Institutional Research and Planning Analysis department. However, this information is not available in the form that can be readily used or interpreted. Two undergraduate students collected and processed data for several engineering cohorts to analyze GPA trends, graduation rates, and intra-college migration. The processed information is made available through BEEVT web site. Currently, due to the IRB approval limitation, complete details of the analysis are restricted to Virginia Tech users and will be made available to public in future. Some conclusions from this analysis include the following. On an average, the rate of graduation from engineering after 6 years of enrollment decreased from 64% for 1994 cohort to 53% for 1996 cohort. The decline is mainly attributed to a group of students that were admitted to the provisional general engineering (PGE) program that was started in fall of 1994 mainly due to declining enrollments and was discontinued after fall 1999. The PGE students typically lacked math and physics background and did remedial courses before starting regular engineering courses. On an average, 18% of students who enter engineering program have graduated from another college at Virginia Tech after 6 years. On an average, 20% of students who enter engineering program are no longer enrolled at Virginia Tech after 6 years. It was also observed that about 53.6% students graduate from engineering programs within five years and only about 19.5% of the students graduate within four years of joining the program. The retention rates of different cohorts were compared with average SAT scores. Interestingly, it was found that while the average SAT scores went up during 1994-96, the corresponding graduation rates decreased.

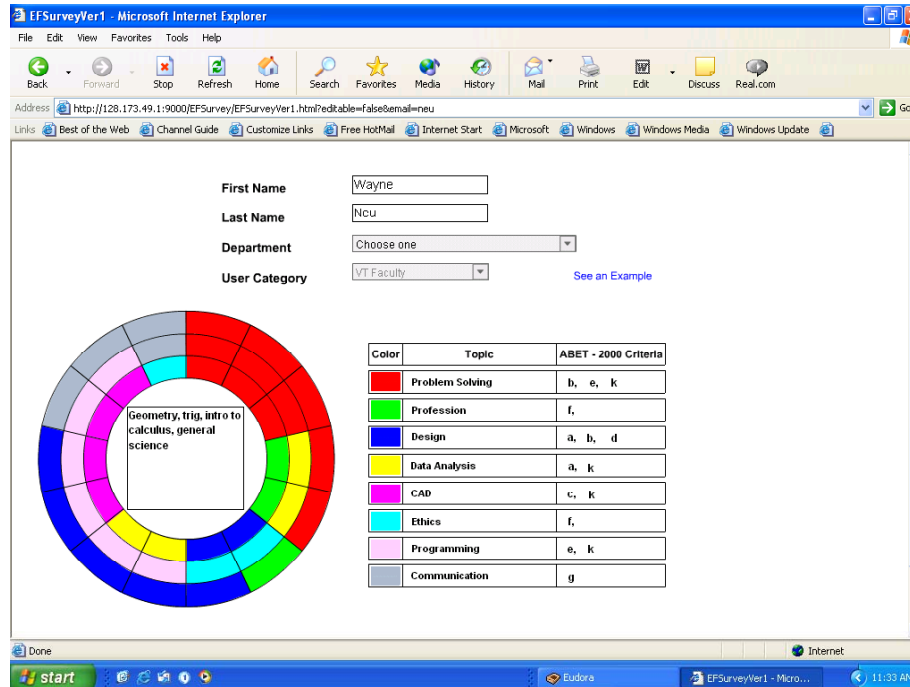


FIGURE 2  
FEEDBACK FROM A FACULTY FROM AEROSPACE AND OCEAN ENGINEERING DEPARTMENT

The undergraduate students also developed the web site of BEEVT ([www.beevt.enge.vt.edu](http://www.beevt.enge.vt.edu)) with assistance from a staff member from the EngE department. In order to provide proper resources/literature on latest pedagogical concepts, academic assessment, etc. to potential engineering education researchers, a list of references has been compiled and is made available through BEEVT web site.

### Development of a Continual Assessment Scheme

One of the major weaknesses in the existing GE program has been the lack of appropriate tools that can be used to assess effectiveness of changes in curriculum. In past, the success or failure of various curricular changes was assessed based on anecdotal evidence. The BEEVT project facilitated collaboration between engineering faculty and experts in assessment and pedagogy for initiating development of appropriate assessment tools. Currently, a number of activities are underway, which are expected to develop scientific assessment tools for assessing changes in GE program. A brief description follows.

#### Use of Electronic Portfolio (ePortfolio)

The beginning of BEEVT project coincided with a university-wide pilot exploring the use of an electronic portfolio system. A sub-committee of BEEVT investigators, representing faculty members in engineering and education psychology, developed plans for the participation of engineering students, ranging from freshman to graduate levels, in the university level Virginia Tech Electronic Portfolio (VTeP) pilot. VTeP enables students to easily create, manage, and share web-accessed electronic portfolios that document their knowledge, skills, and achievements from coursework and from extracurricular activities. The ePortfolio software used was originally developed by the University of Minnesota and is now made available through the Open Source Portfolio Initiative (OSPI). Virginia Tech is a charter participant in the OSPI project and is one of the first universities in the world to successfully implement the OSPI software. Each user is provided a password protected account with 50 MB space. Upon login, the user is presented the option of entering one of the three primary areas of the system, Enter, Share, or View. The Enter option allows the user to record and update portfolio entries. The Share option allows the user to share information from the portfolio with others by creating folders containing only the information that is to be shared. Multiple folders, or custom views, of the ePortfolio can be created and shared with instructors, research partners, and potential employers. The View option provides the user entry into all folders that have been shared with him/her by other VTeP users. More information about the system is available at <http://eportfolio.vt.edu>

Five BEEVT investigators (all faculty in the COE) and 28 engineering students working with these faculty members participated in the pilot. Participation in the VTep pilot was voluntary for all except 15 freshmen. These 15 first semester students were enrolled in both the first and second Introduction to Engineering Courses simultaneously and were required to participate. All freshman participants were instructed to select at least one project from their Introduction to Engineering course to publish in their ePortfolio in addition to any other information or materials they wished to include. Students in Mining and Minerals Engineering (MinE) were instructed to use the VTep software as they saw fit. These students did not use the ePortfolio as part of a particular course. They received minimal guidance from the participating faculty member. The Civil and Environmental Engineering (CEE) student used the VTep in a junior level Fluids Mechanics course. He was asked to include a specific assignment in his ePortfolio. All students were asked to share a view of their ePortfolio with their faculty member (see Figure 3). At the end of the semester, all students were provided with a survey (15 questions) to provide feedback addressing mainly three issues: (i) ePortfolio software evaluation, (ii) ePortfolio development, and (iii) use of the ePortfolio to improve learning. Based on the analysis of students' responses the VTep pilot in fall 2003 was a successful endeavor. Eighty-eight percent of student participants want to continue to use the software, recognizing the benefit in keeping samples of academic work and a record of academic progress. While some see the ePortfolio primarily as a repository for information, others recognize the benefit of the reflection supported by the e-Portfolio. Details of the e-Portfolio pilot are given in [4].

In fall 2004 the VTep will be integrated into the first semester Engineering Exploration course with the goals of helping the students see the relevance of all the courses they will take as engineering students, providing a foundation for life-long learning through reflection, and setting the stage for the thoughtful collection of artifacts to support both student learning and program assessment. The ePortfolios developed by the students will include several specific reflective assignments and materials of the individual student's choice that document his/her growth as an engineer over the semester. All (~1300) students enrolled in the first semester GE course will participate in the pilot.



FIGURE 3  
FRESHMAN STUDENTS WORKING ON DESIGN PROJECT – PART OF DESIGN PROJECT DOCUMENTS POSTED TO E-PORTFOLIO

#### Online survey for Class Profile

For last 3 years, the EngE department has been conducting a survey of all incoming engineering freshmen during summer orientation with an objective to create a profile for entering class including students' academic background, hobbies, experiences in engineering type activities, etc. Some sample questions asked in this survey are:

- Did you take a computer aided design class during high school?
- Do you have a personal website that you developed yourself?
- Did you grow up on a farm?
- Have you ever worked for or with an engineer doing engineering-related work?



Although this data is available but a systematic analysis of data has not been done to link profile of the entering class with its academic success and other related variables. Recently, a couple of EngE faculty members held consultations with an expert in academic assessment and starting fall 2004, this survey will be administered online with the help of our assessment expert. Processed data will be available to all for further analysis.

#### Assessment of Freshman Engineering Courses

As mentioned earlier, freshman engineering courses in GE curriculum have undergone significant changes in last five years. However, a systematic scheme to assess the effects of these changes has not been developed yet. In the 'Engineering Exploration' course Matlab programming has been taught for last 5 five years. However, starting Fall 2004 an object oriented programming language called Alice ([www.alice.org](http://www.alice.org)) will replace Matlab programming. This change was introduced primarily to accommodate interests of computer science students who are also included in engineering freshmen class starting fall 2004. A systematic assessment scheme to assess the effectiveness of Alice is being developed in consultation with experts in Alice and academic assessment. It's hoped that the proposed scheme will generate required data and provide information to develop robust assessment tools for evaluating effectiveness of curriculum changes.

#### Development of Proposals for Implementing Activities Planned in BEEVT

A number of joint proposals targeted at implementing and extending engineering education research activities have been / are being developed by the engineering and education faculty since the beginning of BEEVT. A brief description follows:

##### Department-level Reform (DLR) Proposal

This proposal aims to develop crucial linkages between GE curriculum and the curricula in engineering departments using the concept of spiral curriculum. Six EngE faculty and seven faculty members in Biological Systems Engineering (BSE) department collaborated with experts in educational psychology and academic assessment and three faculty members in other engineering department to develop this proposal. This study will undertake department-level reform of the GE curriculum along with the Bioprocess Engineering curriculum in BSE department. The Bioprocess Engineering option within BSE was selected because it is a relatively new program in the emerging field of biotechnology. Since the creation of the Bioprocess Engineering option about five years ago, the student enrollment in this option has increased in size from about 5 students to 20 students and it is expected that enrollment will double within the next few years. This rapid growth has provided the faculty with new educational challenges and a perfect opportunity to collaborate with the ENGE faculty to work on curriculum reforms. The proposed reforms include adopting the concept of spiral curriculum for linking GE curriculum with the Bioprocess Engineering curriculum. The twentieth century psychologist, Jerome Bruner, proposed the concept of the spiral curriculum in his classic work "The Process of Education." [5] Bruner advocates that a curriculum as it develops should revisit the basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them. Further, he proposes structuring a curriculum around the great issues, principles, and values that a society deems worthy of the continual concern to its members. In the proposed GE – BSE curricula reformulation, a theme of sustainability has been selected to provide a contextual framework. The supporting principles of design, ethics, and a systems approach and cross-cutting skills of communication, teamwork, life-long learning, research experience, and lab experience will be woven throughout the curricula. In the reformulated GE and Bioprocess Engineering curricula, students will apply the supporting principles of engineering (design, ethics, systems approach, etc.) to problems related to sustainability. During the freshmen year in GE program, theme related problems would be dealt with on a lower level or using simulation models like the Alice system and laboratory exercises that do not require upper level curriculum knowledge. As the student progresses through the curriculum, the same and new sustainability problems will be addressed with increasing sophistication using more recently acquired skills and knowledge from engineering and other courses. Successful implementation of this proposal will be used as a model for incorporating similar reforms in other engineering departments in the College and elsewhere. The investigators have received informal approval of this project from the NSF as of this writing.

##### Center for Learning and Teaching Proposal

Two BEEVT investigators (one engineering and another technology education) collaborated with a group in North Carolina A & T University investigators to develop this proposal that is under consideration at NSF.

##### IGERT Proposal

Several BEEVT investigators (both engineering and education faculty) developed a preliminary proposal for the Integrative Graduate Education and Research Traineeship Program (IGERT) program of the NSF and it's currently under consideration. The primary aim is to develop a doctoral program in engineering education.

### TPC and Other Proposals

A group of engineering and education faculty is currently working on developing a research proposal to the Teacher Professional Continuum (TPC) program of the NSF. The primary aim is to launch a collaborative study that evaluates the pedagogy and effectiveness of various engineering design activities and the role of virtual tools like the Alice in engineering design. A team of engineering and education faculty will be visiting NSF to discuss this proposal idea in third week of August. This will be the third such joint visit of NSF by the engineering and education collaborators. The TPC proposal will be submitted in September 2004.

In addition to above, the BEEVT investigators have plans to submit proposals to the Course, Curriculum, and Laboratory Improvement (CCLI) and Engineering Education program of the NSF in coming months.

## SUMMARY

The engineering –education collaboration that primarily began with BEEVT project in 2003 has started yielding significant results. This interdisciplinary group has already made three conference presentations [1] – [3] on their collaborative activities. The group has recently received informal approval of a major 3-year engineering-education research grant from the NSF to improve engineering pedagogy using research in cognitive science and learning theory. This early success will definitely excite and encourage faculty members in other engineering departments to consider collaborative research with EngE faculty for improving engineering education. EngE faculty is working on developing procedures to allow faculty members from other departments to serve as ‘affiliated’ faculty members in EngE department for carrying out interdisciplinary research. The EngE department will offer a graduate program both at Masters and Ph.D. levels in engineering education starting Fall 2005.

## ACKNOWLEDGEMENT

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