

# **INNOVATIONS IN MULTIDISCIPLINARY ENGINEERING PROGRAMS: FOCUS ON MULTILEVEL COMMUNICATION SKILLS**

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## **Abstract**

Multidisciplinary engineering programs are uniquely positioned to integrate new educational and research initiatives into their curricula. In this paper, we describe an integrated series of continuing innovations in the Engineering Science and Mechanics Department, College of Engineering at The Pennsylvania State University. These innovations include: the introduction of undergraduate student portfolios; the adoption of a new perspective on “Design” for the ABET program criteria; enhancement of the senior research and design project through incorporation of the ABET professional components; incorporation of non-technical abstracts in both undergraduate and graduate theses; professional development seminars for both undergraduate and graduate students; the introduction of an informal education seminar to prepare PhD students wishing to pursue academic careers; and introduction of new courses to support the department’s strategic plan. With an underlying focus on the development of multilevel communication skills, the aim of these initiatives is to foster an interdisciplinary and multidisciplinary environment that produces internationally competitive engineers.

## **The Environment for Multidisciplinary Engineering**

The Engineering Science and Mechanics (ESM) Department at The Pennsylvania State University will celebrate, in 2005, its centennial year and its fiftieth year of Honors education for the College of Engineering. Currently, the department comprises 27 tenured/tenure-track faculty, 90 undergraduate students (65 Engineering Science juniors and seniors) and 100 graduate students. The following degrees and programs are offered by the ESM Department: BS (Honors) in Engineering Science; minor in Engineering Mechanics; MS in Engineering Science; MS in Engineering Mechanics; MEng in Engineering Mechanics; and PhD in Engineering Science and Mechanics. Research expenditures in 2003 exceeded \$15,000,000, reflecting the department’s core strengths in materials, mechanics and nanotechnologies. The faculty is highly multidisciplinary with degrees in mathematics, physics, chemistry, engineering science, and aerospace, civil, electrical, materials, and mechanical engineering. Consequently, faculty and student collaborations are widespread both within the College of Engineering and across the University (including the Colleges of Science, Earth and Mineral Science, Agriculture, and Medicine, the Materials Research Institute and the Huck Life Sciences Institute) – activities that

are strongly encouraged by the Department. Collaborations with other universities, in the US as well as abroad, are also strong.

The undergraduate degree program aims for depth in mathematics and the sciences, and breadth in engineering courses that can be taken from six different departments. It includes twelve credits (four courses) of technical electives plus seven credits for a senior research and design thesis project that can be customized by the student to provide depth in an area of their interest. The graduate programs require a strong foundation in applied mathematics and engineering science, with a specialization selected from the areas of mechanics, materials, electricity and magnetism, or the biological sciences. Both undergraduate and graduate programs have a high degree of flexibility to foster interdisciplinary and multidisciplinary perspectives on a student's chosen field of study.

The ESM Department's strategic plan for 2005-2008 proposes to build on current strengths in nanotechnologies, materials and mechanics to develop new curricular and research initiatives in three multidisciplinary areas:

- (i) Bio-nano Science and Engineering;
- (ii) A Center for Multiscale Wave-Materials Interactions; and
- (iii) Health Monitoring – for Structures, Systems and People.

The bio-nano science and engineering initiative requires the department to address the integration of foundational biology courses into a curriculum that is currently strongly grounded in the physical sciences. The Center for Multiscale Wave-Materials Interactions brings together faculty with expertise in wave behavior to discover new synergies that occur when combinations of energies (microwave, laser, X-ray, ultrasonic, acoustic, electron beam, etc.) interact with matter – including biological materials. The health monitoring initiative broadens the concept of applying nondestructive evaluation techniques to assess not only the integrity of engineering structures but also biological systems in general and the human body in particular.

If such initiatives are to be successful, a new generation of students who are conversant with the engineering, biomedical, and life sciences disciplines must be nurtured. The key to their academic growth will be new levels of communication among the scientists and engineers from the respective disciplines on the one hand, and with the lawmakers, policy makers, business professionals, and the general public on the other hand. In this paper, we discuss recent initiatives in the ESM undergraduate and graduate programs with an underlying focus on such multidisciplinary communications among academia, industry, and the general public.

### **New Initiatives for Undergraduate Education**

Communication is critical to the success of each and every student completing an undergraduate degree, whether they plan to continue their studies in graduate school or enter the workforce. Feedback from industrial advisors and the Accreditation Board for Engineering and Technology (ABET) continues to emphasize communication skills as a primary attribute sought during the hiring process. Due to the nature of the flexible, multidisciplinary undergraduate curriculum, communication skills are particularly important to individuals graduating from Penn State's Engineering Science honors program so they can convey, to those unfamiliar with the

curriculum, the true breadth and depth of their undergraduate experience. The ESM department has instituted the following changes at the undergraduate level to assist in the development of these crucial communication skills.

### ***Portfolio Reflections***

In 2000, the Engineering Science program began using student portfolios as a means to assess the quality of the undergraduate program. Portfolios are viewed as moving away from the old accreditation model of ‘bean counting’ toward a deeper and more flexible means of assessing a diverse program in which students are encouraged to find unique combinations of courses and activities to suit their various educational objectives. When portfolios were first introduced, a checklist was circulated which highlighted a list of prospective items to be submitted for the portfolio. Unfortunately, this list was initially viewed by both students and faculty members as a list of required items and quickly became just another form of “bean counting”. These items were often submitted and then never looked at again.

In an effort to transform the portfolio from simply a repository of work completed to a means for continuous evaluation of student progress, several changes were made in 2004 regarding the administration and evaluation of student portfolios. First, the checklist for the portfolio was removed and students are now encouraged to view their portfolio as a means of continuously gathering ‘evidence’ of the capabilities they are developing during their undergraduate years. Second, the students are now required in each semester of their senior year to review their portfolio and reflect on their own personal capabilities that are evidenced by the included items, ultimately removing some items and/or adding others to create a more complete picture of the student’s abilities. Third, faculty members are being trained to review the portfolios with the students each semester and to use student feedback as a means for assessing progress towards meeting the Engineering Science program objectives.

While the structure of the portfolio is decided by each individual student, the ESM Department encourages them to consider four main themes:

- (i) Design,
- (ii) Communications,
- (iii) Teamwork and Leadership, and
- (iv) Academic Excellence.

In their written portfolio reflections, the students are asked to consider that some items may show evidence in more than one category. For example, students at Penn State enrolled in the first year Engineering Design and Graphic course typically complete a group design project at the end of the semester. Often a written report or a Power Point presentation is required. Many students choose to include this item in their portfolio because it shows evidence of their initial design capabilities, gives some indication of their ability to work in a team, and demonstrates a component of either their written or oral communication skills at the start of their undergraduate studies. At the end of their program, each Engineering Science student is required to write and defend a thesis on their senior research and design project. This often serves to highlight, in comparison to the first year items, how the student’s abilities have matured during their undergraduate years.

In addition to academic items, students are also encouraged to include items from extracurricular activities that further demonstrate their abilities in one or more of the four key areas. For example, students involved in Penn State's Dance Marathon have submitted a report of their committee's activities as evidence of both teamwork and leadership, and communication abilities.

Over the last year, students have been quite pleased after taking the time to view their undergraduate education in this light. Many have indicated that the act of writing a reflection on their portfolio specifically and their undergraduate experience in general made them much more fluent during the interview process when asked to discuss their personal strengths. In the coming semesters, the reflective portfolio activity will be extended to semesters earlier than the senior year, ultimately transforming into a process that many of our students will participate in every semester of their undergraduate program.

### ***Broad Description of Engineering Design***

Design has always been a major focus of the accreditation requirements for undergraduate engineering programs. However, due to changes in the ABET accreditation requirements that no longer rely on a certain number of credits designated as "design", our students and faculty were challenged to find concrete ways of documenting and communicating their design activities in both undergraduate courses and undergraduate research activities. Due to the multidisciplinary nature of the Engineering Science program, it was necessary to develop a clear description of design that encompasses a wide range of activities. In response to this challenge, the following two paragraphs present the ESM definition of engineering design as developed by the department's undergraduate curriculum committee and approved by the faculty.

Design in the Engineering Science curriculum has a broad interpretation. For Engineering Science faculty members and students, design is a creative and iterative process that encompasses systems, components and processes related to, for example, material, biological, chemical, mechanical and electrical systems. Within these systems, design is performed at length scales ranging from nanometers (at the atomic level) to tens of meters (the length scales associated with our everyday experiences). The tools used for design include mathematical models (their development and iterative refinement), algorithms (of all sorts), computer simulations, experimentation and prototyping. These tools are integrated to achieve the objective of the Senior Research and Design Project.

This project, which culminates in an oral presentation and a written thesis, incorporates design in a variety of ways befitting an interdisciplinary department. Engineering Science students participate in projects in all engineering disciplines and employ design principles before, during, and after analysis, experimentation and/or simulation. The resulting designs of systems, components or processes are then tested and refined by changing material, geometric, stochastic or other parameters, as required. The design is often not a machine component or a bridge, but may be a new experimental process, nanoscale device, or computer code for the modeling and/or analysis of an engineering system or process. Computer programs written initially to analyze, are frequently rewritten to function as design tools. As appropriate, knowledge of physics, chemistry, mathematics, mechanics, materials science, etc., is harnessed along with the iterative

nature of design to complete an independent research project, within a team-based environment, in a timely manner.<sup>1</sup>

### ***Design and Professional Components Summary***

In addition to identifying the design activities in the curriculum and the senior research projects, Engineering Science graduates must be aware of a variety of less technical yet equally important issues they will encounter in their working life. ABET describes several of these issues in its Criterion 4 as professional considerations that include the economic, environmental, sustainability, manufacturability, ethical, health and safety, social, and political aspects of the engineering profession.<sup>2</sup> In addition, students must be made aware that an increasing proportion of engineering practice takes place on a global, rather than national scale; most working engineers must function as a member or leader of a multidisciplinary team involving the management of people, time, and money; and professional development and lifelong learning are vital in all areas of the engineering profession.

To address this growing need for the development of professional skills beyond the math and science focus of the bachelor degree program requirements, the ESM Department has instituted an undergraduate seminar series to introduce seniors to a variety of professional issues. While each seminar begins with a 15- to 20-minute presentation, the primary focus of the seminar is placed on the 30-minute discussion that follows the presentation, allowing the students to obtain a deeper, more personal insight into the topic by debating the issues and tapping into the speaker's personal experience through direct questions. As a 50-minute presentation on any one of these subjects is insufficient for the students to become experts, the goal of the seminar series is to make the students aware that these issues exist and to 'jump start' their thinking about the broader, less technical aspects of the profession. In this way, students should be much better prepared to address these issues when they occur in the workforce.

The topics discussed during the last year have included: Engineering Ethics; Identifying Design; Safety; the Role of Research in Product Development; Global and Environmental Engineering Issues; Managing Technical Projects: Time/Task, People, and Financial Management; Government, Public Policy, and the Engineering Profession; Graduate School – is it right for you?; and Professional Societies and Life-Long Learning. Speakers were recruited from a variety of industrial locations including Lockheed-Martin, ALSTOM, and Sarnoff Corp. and the government research facilities of NSWC and NAVSEA. Speakers have also consisted of faculty members in the ESM department as well as an Associate Dean and a Department Head from Penn State's College of Engineering. From this diverse combination of speakers and topics, our seniors now leave with a much broader perspective on the engineering profession.

As a measure of this broader perspective and toward the goal of increased communication skills, the Engineering Science seniors are now required to include a Design and Professional Components summary in their written research thesis. In addition to identifying the varied design components of the thesis work, this summary provides a valuable means for students to give serious consideration to the broader implications of their thesis research. The act of identifying and summarizing these considerations further enhances the ability of Engineering Science students to communicate the breadth and depth of their undergraduate education.

## **New Initiatives for Graduate Education**

Communication is a key component of any research enterprise. Whereas detailed results and conclusions must be presented to peers, proposals and reports have to be submitted to employers and research sponsors. Also, although not emphasized in the past, there is now an ever-increasing pressure to broadly disseminate information on research trends as well as key results that are conceivably of public interest. The ability to conduct several conversations simultaneously at different levels of technical jargon, formal nontechnical language, and colloquialisms must be acquired by any researcher-in-training who wishes to work in a democratic state with a high level of literacy, legislative control of public expenditures, as well as widespread stakeholding in commercial and industrial institutions.

The ESM Department has recently undertaken three initiatives to foster the development of the ability to converse on one's research topics with specialists as well as laypersons.

### ***Graduate Seminar Course***

The requirements of a MS degree in the ESM Department include the acquisition of two academic credits from a prescribed 1-credit seminar course, and those for a PhD degree include three more such credits. The MEng degree requires one such academic credit. This seminar course was restructured into a mixture of educational, professional development, and reflective components.

Of the 36 seminars conducted in the Fall 2003, Spring 2004, and Fall 2004 semesters, 26 must be classified as technical seminars. The research areas addressed in the technical seminars included bio-nano science and engineering, continuum mechanics, dynamical systems, and a broad spectrum of material properties and structures. This diverse selection was consonant with the interdisciplinarity as well as the multidisciplinary that characterizes the ESM Department. As no more than 20% of the roughly 35 graduate students enrolled every semester for the seminar course could consider themselves as specializing in the research area addressed in a specific seminar, all speakers were requested to spend the first 20 minutes in educating the audience before discussing specific investigations and conclusions. Thus every graduate student functioned sometimes as a junior peer, sometimes as a technically astute layperson, and sometimes as an interested but ignorant layperson, during the seminar course.

Ten seminars during the three semesters were geared for professional development of researchers-in-training. Graduate students were apprised of issues relating to engineering ethics, sustainable development, public outreach activities, technology management, and intellectual property. Feedback from students revealed that most had been largely ignorant of these issues prior to the seminars, and were happy to have been enlightened.

The reflective component took the form of ten seminar reports per semester that had to be submitted by every student within 48 hours of a seminar. Each report was required to have 3 sections: a 200-300 word summary of the seminar, followed by the student's assessments of the importance and the future of the topic, and concluding with about 100 words on the style of delivery and any hints garnered by the student on improving his/her own style of formal presentation. The reports were graded by the Seminar Coordinator on the extraction of the key

issues of a seminar, prediction of research trends, and identification of best practices for oral communication of one's research to specialists and technically astute laypersons. In order to promote reflection by students, graded reports were returned within 72 hours of the submission deadline.

Thus, listening, comprehension, writing, and self-assessment abilities of graduate students were impacted by the restructured seminar course. Although a systematic analysis of grades was not performed, the Seminar Coordinator noticed steady improvement in the writing skills of all graduate students, whether from the US or international, and regardless of a student's native language.

Further confirmation came from the results of an English Competency Test (ECT) that every graduate student must pass before admission to doctoral candidacy. The ECT has oral as well as written components. Although US graduate students generally pass the ECT easily at the first attempt, a large majority of international students from non-English-speaking countries had been required to take remedial courses in writing and presentational skills. During the Fall 2004 semester, all graduate students, passed the ECT to the examiners' satisfaction.

### ***Multidisciplinary Informal Engineering Education Seminar (MIEES) Course***

A new 1-credit seminar course was started in Fall 2003 semester, under the aegis of the NSF-funded multi-university Center for the Integration of Research, Teaching, and Learning (CIRTL).<sup>3</sup> Penn State and Michigan State Universities are the two junior partners of the University of Wisconsin-Madison in CIRTL. This center rests on the twin pillars of

- (i) the acceptance of teaching as a research process, and
- (ii) the creation of learning communities that favor teaching as a research process.

CIRTL is committed to the development of a nationwide ethos whereby science, technology, engineering, and mathematics (STEM) faculty members undertake the scholarship of teaching<sup>4,5</sup> in addition to discipline-specific research activities.

CIRTL researchers are organized in nine different teams, one of which is focused on informal STEM education. Informal education is an essential part of the post-PhD lifestyle, whether one actually joins an institution of learning or works for a research group in any setting. In either situation, a researcher has to function as a spokesperson for research — his/her own as well as of collaborators and juniors. The ability to speak informally about research is also a great asset for a faculty member in inspiring freshmen and sophomores towards more challenging upper-division courses and even graduate studies.

Furthermore, all researchers shall have to participate in their community affairs as a citizen. Some of them may join the municipal legislature, the local school board, the state legislature, or even the federal legislature. Others may depose before select committees, or be appointed to oversight boards. Still others may choose to impart their personal visions — as scientists, engineers, and/or mathematicians — of the future to schoolchildren by visiting nearby schools.

The main objective of the MIEES course is to enable a graduate student to identify two essential features of any research area, and to use both features in informal education activities. The two features are labeled as the *glory* and *essence*. The glory of a research area is that which inspires a researcher to undertake its activities. The essence is the simplest statement of a fundamental principle which makes the chosen research area glorious. For instance, if the research topic is thermodynamical, the essence of thermodynamics can be communicated by explaining that a fan stops after the electric plug has been pulled out from the wall socket. The glory of thermodynamics is that we can send astronauts to the moon and bring them back safely. Depending on the sophistication of the audience, an informal engineering educator should relate both features of his/her own research topic, highlighting the basic conclusions drawn therefrom and their present as well as predicted consequences.

The MIEES course was designed to be action-oriented. Every graduate student has to deliver a 25-minute presentation on his/her research topic on an appointed day during the first part of the course. Every presentation is videotaped, and other students take down notes during the delivery. The videotape is given to the presenter at the end of the presentation. The following week, fellow-students as well as the Seminar Coordinator provide written feedback, and the presenter submits a self-critique. After the cycle is over for all participants, each student is required to submit a two-page report on his/her presentation, as if it were a press report in the Science Times section of the New York Times. The Seminar Coordinator provides feedback on the initial version of the press report, and a final version is to be handed in by the student towards the end of the course.

In the second part of the MIEES course, every student has to deliver an improved but 20-minute version of his/her earlier presentation. Other participants as well as the Seminar Coordinator grade improvement and adherence to the feedback provided by them earlier. The presenter also has another opportunity for self-assessment.

During the last meeting of the course, an oral self-assessment of the changes in his/her outlook on informal education activities has to be presented by every student.

Video as well as written records of the entire course for the Fall 2003 semester were analyzed by an assessment team from CIRTL.<sup>6</sup> In addition, all participants were interviewed by the assessment team. Three graduate students were from the US, and three from the People's Republic of China. A US graduate student who served as the Project Assistant was also interviewed. All students were males working towards the PhD degree.

According to the assessment team's report, every participant reported that the videotapes of his presentations offered the first opportunity for the presenter to see himself as a speaker. This aspect of the MIEES course was reported to be very useful for improvement. Feedback from other participants was felt to be useful by some, but not all, participants to learning about their nonverbal presentational skills. All international students underscored the significance of videotapes and written feedback, but all US students downplayed the importance of written feedback.

All participants were able to define both glory and essence of their topics, and found that both features helped them organize their presentations better. Evidence of conceptual change varied:



whereas two reported knowing about informal education before taking the MIEES course, four had only minimal prior knowledge at best. After the conclusion of the course, the majority became interested in acquiring more informal-education experience. All students stated that they began to modify their presentations, controlling their delivery, emphasizing certain points but not others, after watching the videotapes of their first presentations.

The Seminar Coordinator felt that his satisfaction with the MIEES course was encapsulated by one student's response to the assessment team: "It got me my job. I used these techniques for my job talk. If no one else worked on what you worked on, tell them why it is important, why it is awesome. There are different meanings in different fields. It is critically important to use the things we learned in class for a job talk."

The MIEES course was also conducted in the Fall 2004 semester, also with six graduate students, all from the US. The course records will be examined by the CIRTL assessment team in 2005, and comparisons shall be made with the conclusions drawn from the Fall 2003 offering.

### ***Nontechnical Abstracts for MS and PhD Theses***

Graduate theses and dissertations are scholarly compilations of research investigations and results with detailed treatments of methodology and presentations of preprocessed data for other researchers to consult. In many cases, a bound thesis may be read only by a few students in the research group of the advisor of the author. At first glance hence, graduate theses may seem unlikely to provide opportunities for innovative practices.

Perhaps, the most important part of a graduate thesis is the abstract, which is a distillation of the motivation, the methods, and the conclusions reported in the body of the thesis. It is akin to an executive summary. University libraries often put up thesis abstracts online for easy access by all.

However, a huge majority of readers will find thesis abstracts incomprehensible, given the high levels of jargon employed for brevity's sake. Informal surveys in the ESM Department provided confirmation: the multidisciplinary of this department, representing a small fraction of all academic STEM disciplines, ensures that most graduate students are unable to understand departmental theses in research areas different from theirs. Undoubtedly, this is a serious barrier to interdisciplinarity that today is often the hallmark of cutting-edge research.

In order to surmount this barrier, the departmental faculty decided in late Fall 2003 that every MS or PhD thesis must contain a nontechnical abstract as the last appendix. Between 500 and 1000 words in length, the nontechnical abstract should aim to inform laypersons on

- (i) the context in which the research was undertaken,
- (ii) the chief contributions reported in the thesis, and
- (iii) the broad impact of those contributions.

Technical jargon must be kept to a minimum. Mathematical symbols, graphs, and figures must not be used.

The nontechnical abstract has to be approved by the Master's Committee or the Doctoral Committee, as appropriate. Therefore, the nontechnical abstract must be a part of the thesis draft submitted by the graduate student to his/her Committee.

A copy of the draft nontechnical abstract has to be electronically sent to the Graduate Secretary of the department for circulation to all faculty members, undergraduate students and graduate students two weeks before the thesis defense.

Inclusion of the nontechnical abstract became mandatory in Spring 2004 semester. As of Dec 15, 2004, seven PhD and 20 MS theses (bound volumes in the departmental library) written by ESM graduate students had nontechnical abstracts. Every year, all nontechnical abstracts shall be archived on the departmental website in order to serve as

- (i) a recruitment tool for new graduate students,
- (ii) an advertisement tool for prospective employers, and
- (iii) an informal-education tool for society at large.

The success of the nontechnical abstracts in the graduate theses has resulted in this practice also being adopted in the undergraduate Senior Research and Design Project Theses.

### **New Curricular Developments**

The department's strategic initiatives in bio-nano science and engineering and multiscale wave-materials interactions provided a remarkable opportunity to develop courses that are multidisciplinary in content from their inception.

An in-depth review of the Engineering Science undergraduate curriculum revealed that both quantum and statistical mechanical concepts could be taught more effectively through a course entitled "Engineering Applications of Wave, Particle and Ensemble Concepts" – a course that would be the foundation for a new undergraduate minor in nano science and engineering. The core curriculum is currently being modified to enable students to take two biology/bioengineering courses as a foundation for a "biological" emphasis in the Engineering Science program. This is being accomplished without sacrificing the mathematical and scientific rigor that is the program's hallmark.

Six categories of courses were identified for the nano science and engineering minor and include: fundamentals; synthesis and processing; characterization; simulation and design; applications; and manufacturing. Within the ESM Department, the following new courses were developed to support the minor:

- Simulation and Design of Nanostructures;
- Electronic Properties and Applications;
- Optical nano-electro-mechanical systems and micro-electro-mechanical systems (NEMS/MEMS);
- Simulation and Design of Nanostructures;
- Introduction to Biomolecular Materials; and

- Bio-Micro and Bio-Nano engineered systems.

Courses from other departments may be substituted with permission of the advisor.

At the graduate level, the multiscale wave-materials interaction initiative is developing a new graduate concentration and future graduate certificate program in laser-materials interactions. This program is being developed with collaboration among the engineering science, mechanical and nuclear, industrial and manufacturing, electrical, and materials science and engineering departments as well as the Electro-Optics Center (EOC), the Applied Research Laboratory (ARL) and the Materials Research Institute. The following five graduate courses are being developed as parts of the initiative:

- Laser Optics Fundamentals;
- Laser-Materials Interactions;
- Laser Integrated Manufacturing;
- Laser Microprocessing; and
- Laser Laboratory.

They address the interactions of lasers with materials, problem-solving, manufacturing using lasers at both the micro- and macro-scales, and new product development. Through Penn State's World Campus and the >300 companies associated with EOC and ARL, these course have potential for outreach to a highly diverse audience.

Curricular initiatives of the breadth and scope described above are multidisciplinary by their very nature and require a multidisciplinary community to foster their growth. They must address problems at multiple levels that may include, for example, fundamental principles, basic materials or building blocks, devices, and systems. Departments such as ours (or their multidisciplinary equivalents) are in an excellent position to lead such initiatives, which are becoming increasingly important to the global community, because a diversity of disciplinary languages are used therein and multidisciplinary communication promotes the emergence of new paradigms

### **Concluding Remarks**

As we look towards the future global workforce, it becomes increasingly clear that the dichotomy between science and engineering is a false perception. Science and engineering not only complement each other but are totally intertwined. Tomorrow's cutting-edge technologies must integrate a diversity of disciplinary concepts, multiple skills, communications across disciplinary languages, and a receptiveness to new schools of thought. When the Engineering Science program was conceived and founded in the 1950's and the Department of Engineering Science and Mechanics Department was created in the mid-1970's, the university unwittingly discovered the correct disciplinary mix for the 21st century. Somehow, in the last twenty years, this vision became obscured, only to be discovered again with the almost concurrent emergence of the bio-, info- and nano-technological revolutions. Now is the time to re-emphasize the value of multidisciplinary engineering education and research, and to embrace the biological and biomedical sciences as the next frontier for engineering integration. With an underlying focus on

multilevel communication skills, the initiatives described in this paper are a first step towards achieving this vision.

## References

1. Engineering Science Undergraduate Program Guide 2004 pp 21-22.
2. Criteria for Accrediting Engineering Programs, Engineering Accreditation Commission, 2001.
3. <http://cirtl.wceruw.org/>
4. E.L. Boyer, *Scholarship Reconsidered: Priorities of the Professoriate*, Carnegie Foundation, Princeton, NJ, 1990.
5. K. Trigwell and S. Shale, "Student learning and the scholarship of university teaching
6. L.D. Weaver and C.L. Colbeck, *Assessment of Informal Education Initiative: Engineering Science and Mechanics 597A*, Penn State Center for the Study of Higher Education (Dec 9, 2004).

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Professor Judith A. Todd is the P. B. Breneman Department Head Chair of the Engineering Science and Mechanics Department at The Pennsylvania State University. She received her BA (1972) and PhD (1976) degrees in Materials Science from Cambridge University. Dr. Todd currently serves as the Director of Penn State's Center for Multiscale Wave-Materials Interactions.

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Christine Masters is an Assistant Professor and Undergraduate Coordinator in the Engineering Science and Mechanics Department at Penn State. After receiving a BS in ME in 1987 and a PhD in ESM in 1992 (both from Penn State), she has worked part time teaching introductory mechanics courses and coordinating advising efforts while raising her four children. In addition, she has been lead developer on the MechANEX project since 1998.