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NSF Sponsored Innovation in Engineering and Computer Science

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Engineering and Computer Science education is in the throes of a far-reaching and exciting process of change which will probably have more impact on what is taught and how it is taught than has had any of the preceding smaller scale revolutions with the possible exception of the original transition from the apprentice system to the founding of the first polytechnics. The National Science Foundation has sponsored curriculum development, laboratory improvement and faculty enhancement projects in the sciences, mathematics and engineering for several years. The engineering curriculum activities have been focused on the introductory portions of the curricula where the greatest needs were identified by the engineering community. Large scale, multi-school projects known as the Engineering Coalitions Program are also underway and the considerable activities conducted under the aegis of those NSF programs are being reported elsewhere. In this paper which is in the form of a report, leavened by some observations and speculation, we describe the curriculum projects which have been sponsored under the direction of the NSF Division of Undergraduate Education, DUE, (a recently minted title) under the Undergraduate Course and Curriculum Program and attempt to define the trends which these projects represent. Another program which is a force in the evolution of curricula is the NSF/DUE Instrumentation and Laboratory Improvement Program (ILI) and its subprogram, Laboratory Leadership Development, (LLD) where the experimental component of curricula is the focus. The process by which these grants are made by the Foundation requires some description. Detailed program announcements are mailed to schools, departments and individuals with a specified closing date for the submission of proposals. All proposals are reviewed by panels that include individuals with expertise in the various fields of engineering and who bring the perspectives of faculty, academic administrators, industry and government to the process of evaluating proposed projects. The set of schools from which reviewers are drawn is very diverse and includes community colleges, small and large schools of engineering and large four-year institutions including those which are research-oriented. The advice of the panels is weighed heavily in the award process while additional information and assessments of a project's impact also enter the decision process. A relatively small set of categories is adequate for classifying most of the supported projects in Engineering and in Computer Science: Introductory Courses and Curricula; Enhancement of Design Education; Software for Instruction; courses aimed at developing Technological Literacy or alternatively; Literate, Humanistic Technology.

As mentioned above, the program's highest priority is the introductory component of the curriculum where the opportunity exists to make the study of these disciplines more attractive to all prospective students and to create experiences which will provide and strengthen motivation. First-year courses must meet these challenges in a context in which many students, irrespective of background, are stressed by the transition to

college life and study. At the same time, few students have any knowledge about the practice of engineering or the work of persons trained in computer science and the inescapable linearity of the curricula places the beginning students largely in foundation courses in the disciplines needed for their majors. As a response to this well recognized problem, programs which develop freshman year courses and curricula have been proposed and sponsored. Two prominent examples of first-year curriculum projects are the "Integrated First-Year Curriculum" at Rose-Hulman Institute of Technology and "An Enhanced Educational Experience for Engineering Students (E4)" at Drexel University. Both of these projects aim at breaking down the compartmentalization of knowledge which is the hallmark of traditional educational strategies while empowering the students with workstations and software which confers considerable problem-solving capability upon them at an early stage of their studies. A more recent program at the University of Texas is strongly focused on the challenge of reducing attrition among Electrical and Computer Engineering students. The course seeks to build problem-solving skills in particular while emphasizing the connections among the calculus, physics and introductory electrical and computer engineering materials. Under the leadership of California State University at Los Angeles, faculty from ten universities are collaborating to develop a model introduction to engineering course which will draw upon the experience of individuals who have been teaching successful orientation courses to minority students. A project at the University of New Hampshire is directed at senior high school students as well as college freshmen and utilizes a video in conjunction with class projects to convey a message about the opportunities in engineering for all students and the importance of acquiring technical understanding. Efforts in the field of Computer Science reflect the recommendations of the Association for Computing Machinery (ACM) and in particular are aimed at broadening the first year courses to go beyond just software development (e.g. Clemson University) by linking the study to mathematics (SUNY Geneseo, Oberlin College, New Mexico State). Earlier use of laboratories and an emphasis on "hands-on" experience also characterize many of the projects, e.g. University of the District of Columbia, Colgate University, Oberlin College). A project at Virginia Commonwealth University is specifically directed at increasing retention of students who might otherwise be diverted from the study of computer science while the general student is the intended audience for the Brooklyn College project which develops a mathematical and computer literacy component for the school's core curriculum and which will embody a digital logic laboratory also. At R.P.I. a new freshman course which integrates linear algebra with the treatment of elementary mechanics will be taken by all freshmen.

Enhancement of Design Education

No notion of what was wrong with engineering education was less controversial than the assessment that education in the process of design had fallen into serious disrepair and that the reestablishment of design as a primary skill and necessary experience for engineers was of paramount importance. A twenty-five year old infatuation with analysis and engineering science which had shifted the balance of curricula so markedly was blamed for contributing to the country's loss of dominance in manufacturing. Four of the projects funded under the fiscal year 1989 program, then entitled Undergraduate Curriculum Development in Engineering, were directed at design education. Rapid prototyping technology to augment design courses was the objective of the University of California at Berkeley project, while at Delaware, Intelligent Simulation embeds tutorial functions in mechanical design courseware for linkage and gear systems. At the University of Rhode Island, a single design project is used to weave together the entire

undergraduate curriculum with different parts of the design project being carried out in conjunction with appropriately related courses. A similar curriculum-wide integration based on control system design is underway at the University of Washington and another total curriculum integration which begins with the freshman algorithms course is in progress at the University of Puerto Rico Mayaguez. The concern with design is equally well reflected in the 1991 projects. Freshman engineering design is taught at Colorado State University in conjunction with the fundamentals of computation where software design provides the basis for the teaching of design methodology. Quality through design is the focus of a new freshman course at the University of Miami and the integration of economic principles with design into the traditional engineering science curriculum is the goal of the Georgia Tech project. The necessity for engineers to work in teams is reflected in the 1992 project at Arizona State where a sequel to the first-year design course emphasizes "teaming", critical thinking and communication. At Oregon State, two sophomore level courses in design and manufacturing will catalyze the revision of the upper division courses in the Industrial and Manufacturing Engineering program.

Software for Instruction

The potential of the computer as an aid in instruction has been a natural even obvious area for development. These efforts are directed at creating interactive, tutorial software which makes use of the graphics or visualization capabilities of personal computers or workstations. At Santa Clara University, courseware which demonstrates basic topics of engineering mathematics used in introductory engineering courses is being developed for an X-Windows environment. At Texas Tech artificial intelligence techniques are used to create an entire learning environment through which a student may navigate in order to learn electrical engineering. The environment provides exercises, design problems, feedback on performance, assistance, information and other computational tools which the student may need. At the University of Missouri at Rolla, a computerized kinematics blackboard is being developed for use in teaching machine kinematics. In Chemical Engineering at the University of Washington, a set of computer programs permits calculations for reactor design, fluid mechanics and heat and mass transfer with convenient graphical output and built-in capability for design studies. Electromagnetic Education is the subject of a program, CAEME, under the aegis of the IEEE in which software in all areas of electromagnetics is being collected, developed and disseminated.

"Literacy" and Its Metaphors

The use of the word "literacy" as in "technological literacy" or "computer literacy" is metaphoric and seeks to convey that the skill or competence being spoken of is as basic and essential as is the ability to read and write. This is an exaggeration, to be sure, and does some disservice to that most powerful of intellectual attainments. Nevertheless the metaphoric uses shown above are deeply entrenched in the discourse of the day and must be acknowledged. A number of projects have as their objective the improvement of the understanding of science and the application of science (technology) by students who are not engineering or science majors. On the other hand, there are projects which are aimed at improving the communication skills, oral and written, of engineering students and these courses sometimes use topics drawn from ethics, professionalism or history as the source of the discussion and writing which the courses involve. Two courses for freshmen which contain a significant component of societal or humanistic concern are being given coincidentally by Professors of Civil Engineering. At Princeton the course is entitled Engineering and Modern

Society while at Duke an introduction to engineering is created through the use of case histories. Concern for professionalism naturally is involved in such offerings and it is the focus of the project at Washington State, "Engineering in Society: a Broader Professional Curriculum."

Improved writing in design courses is both the objective and the title of a project in Chemical Engineering at Michigan Tech while developing techniques for teaching communication skills in engineering courses is the focus of a project at the University of Michigan.

Technological literacy for non-majors is the motivation behind the Acoustics Course for Non-Engineering Majors which is being given at Swarthmore College. Several courses in the interdisciplinary section of the course and curriculum program also fall into this category.

Conclusions

The set of projects which has received support from the National Science Foundation is drawn from a large pool of requests which are of such a quality as to make the selection process quite difficult. Many very worthwhile projects cannot be funded with the existing resources. At the same time related high quality projects are supported by the schools themselves while others garner support form other foundations and industry. Industrial support for curriculum development is substantial, particularly in the coalition programs. Given the diversity of needs and of the faculty who are engaged in these innovative and far-reaching projects, there is a remarkable coherence and focus to the major activities underway. Much of what is being attempted makes use of the computer while the intellectual thrusts of all of the developments are heavily in the area of integration of the curricula from the outset and in empowering the neophyte student as soon as is possible in order to enhance motivation for the arduous study which engineering requires. Involvement in design is seen as desirable both for its value as a needed skill and for the sense of accomplishment it confers on even the designer of a simple object. The ascendancy of communication skills over the purely analytical would seem to be on the horizon as the work of U.S. educated engineers continues to shift in response to the globalization of the world economy and the introduction of technologies which alter the substance and methods of engineering work.

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