Journal of Mechanical Design

Editorial

DESIGN EDUCATION COMMITTEE REPORT

Education Committee Overview

In recent years the Design Engineering Division Education Committee has made it its mission to answer two questions:

- Are the design aspects of mechanical engineering being adequately taught?
- What state-of-the-art developments in mechanical engineering should practicing design engineers know about?

We addressed the first question by sponsoring a number of sessions at recent Winter Annual Meetings and at the Centennial Conference. The Special Features section of this issue is devoted to a review of some of these activities. The second question has been addressed by sponsoring tutorial sessions at the annual Design Engineering Conferences and Shows. The tutorial sessions have included such subjects as analysis and synthesis of mechanisms, finite element method, optimization, and microprocessor interfacing.

The Division Executive Committee has recently assigned us a new task—to coordinate the professional development activities within the division. This assignment has added a third question to our mission:

- What are the continuing education needs of the members of the division?

The committee presently has ten very active members, evenly divided between educators and practicing engineers. We would welcome additional members as well as comments from division members relevant to our activities.

RICHARD A. HIRSCH, P.E.
Chairman,
Education Committee

Projects Valuable in Teaching Design

The Education Committee of the Design Engineering Division is concerned with the development of the undergraduate engineering student into a practicing design engineer. One teaching technique which has significant promise in achieving this end is the use of student design projects. Many mechanical engineering curricula already include project work. But the range of offerings covered under this blanket title is very broad—varying in extent and duration, source of projects, completeness required, "realism," and other characteristics. To discover more about how different schools approach design projects, the Committee sponsored two sessions at the 1979 Winter Annual Meeting. A total of nine papers was presented, from as many different schools.

All the authors agreed that teaching basic principles of engineering science is necessary (although one program challenges the traditional approach to this) but not sufficient. An engineer must be able to

1 apply these principles to solving ill-defined problems,
2 work effectively as a member of a team, and
3 communicate the results.

Participation in projects is an excellent way to move students in this direction. The papers presented at the two sessions pointed out some of the significant differences in the nature and manner of this participation at the nine schools represented. The closing discussion focused quite closely on some of the more interesting and/or controversial concepts.

McNeill and Metzger (79-WA/DE-11) discussed a pair of courses at the senior level at Arizona State. The first emphasizes development of a good first design. Teams of three to four students spend the semester working on projects, each of which has a moderate amount of ambiguity in its initial statement. The final result of each is a design proposal which is judged by a panel of faculty and industry representatives. Lectures throughout the semester introduce design-related concepts (e.g., group dynamics and decision making). The second course, offered during the student's final semester, involves each student in an individual effort to design something to a specification proposed by a faculty member—carrying the design through to constructing and testing a working device or system. These projects are done on campus.

Pelan (79-WA/DE-10) discussed a Rutgers course at the senior/graduate level which also utilizes "useful" projects suggested by faculty members—in this case, unusual instructional apparatus for use in mechanical engineering laboratories. Some designs have already been converted into equipment by the University machine shop, while others have been set aside for future use.

Kardos (79-WA/DE-15) described a course at Carleton in which attention is focused on the design experience rather than on the product being designed. Two projects are completed in a single term in the junior year. Students work in teams on "make and break" projects (such as strip-wood bridges), the testing of which (usually to failure) gives excellent feedback on hardware. A substantial measure of "outside reality" is injected into the class by using engineering cases, and by the design experience of doing the projects.

Another project course in which the students build and "test" their projects was described by Seering of MIT (79-WA/DE-13). This is a one-semester sophomore course, in which each student completes three projects. In the first project, each student is given a kit of hardware from which to build a specified vehicle, structure, or other device. When the projects are done, each student operates his/her device in competition with all the other students taking the course. Seering showed a recent movie of such a design competition, featuring spring-operated "tug of war" machines (each designed to stay in one place on a sand table, while causing its opposite number to move closer). In the MIT environment, the competition attracts much general student interest, with friends of the participants attending to cheer them on. The second project requires each student to modify an existing design to satisfy new constraints. In the third project, students are given a general problem statement and expected to design an appropriate solution.

A second group of project courses features project ideas from real commercial/industrial needs. Engelman and Gunther (79-WA/DE-7) discussed a laboratory format used at the senior level at Ohio State, to give students an experience using experimental methods for solution of engineering problems for which satisfactory analytical solutions are not available. While not involving students in the actual design of a product or device, these tasks do require them to devise innovative methods for measuring the indicated phenomena. The projects in this course originate from manufacturers and from faculty consulting.

Lovas of Southern Methodist University (79-WA/DE-6) discussed a two-course sequence at the junior/senior level. Projects are solicited from industry and addressed by students working in teams. Each project results in a final written report and an oral presentation. These projects are meaningful, with the industry "sponsors" normally using the solutions as is, in part, or as a base for further in-house development. Because of this, the final report must contain layout (and often detail) drawings. Each student works on one project each of his final two years, with the senior project normally being more comprehensive than the earlier one.

Nelson and Zinsmeister (79-WA/DE-9) discussed a fledgling program at the University of Massachusetts, in which students work on projects supplied by industrial organizations who trust students with real problems for which they want solutions and are willing to pay the University. A controversial aspect of this program is that a number of "standard" advanced undergraduate mechanical engineering courses have been dropped from the curriculum in order to make room for the extensive project experience. The limited evidence available in the fall of 1979 indicated that the students are not deprived by the absence of these courses; the semi-independent study required to handle the design projects provides essentially the same information. Enough courses are required to ensure that no student misses any of the basic concepts of mechanical engineering, and students working on projects meet twice weekly with their advisors, who can counsel them into appropriate self-study to fill in gaps. It is believed that there is significant value in educating the students to tackle unknown problems, and to develop an understanding and feeling for methodology, rather than simply imbuing them with specific facts.

Smith (79-WA/DE-12) discussed a two-semester course used some years ago at Detroit, involving teams of graduate, senior, and freshman students from engineering and from other disciplines. These teams worked on real problems from urban agencies (e.g., the Detroit Fire Department), with solutions implemented by the agencies. Two unique features were the mixture of different levels of academic experience, and the use of student Project Managers (very carefully selected graduate students) with essentially complete responsibility and authority for the projects.

Finally, in one program the students themselves are the sources of the projects. Richard and Rankin of the Naval Academy (79-WA/DE-8) described a one-semester course for senior marine- and ocean-engineering students. After an introduction via lectures on design-related topics, and discussion of a pair of case-library problems, teams of four students each are directed to suggest needs which might be turned into projects. They are instructed to consider ideas which relate to the ocean or to the Navy, are modest in scope, are within the current technological state-of-the-art, and could produce projects which can be carried at least through preliminary design in one semester. From the ideas suggested by the teams, the instructor picks the most promising, and each student chooses one of these and draws up a project proposal for it. The instructor selects the best proposals, identifies their authors as design team leaders, and has those persons create teams from class volunteers. Each team spends the remainder of the semester generating a design, usually only a preliminary design, although there have been cases where work was carried well along toward a final design. The team writes a final report, and also presents their results to a group of experienced engineers from local industries. Solutions obtained are normally "paper" solutions, as time constraints preclude any extensive effort in hardware.

The papers were well presented, and featured a variety of visuals including Seering's sound movie. Many individual attended both sessions, resulting in a very lively discussion of the material from all nine papers—discussion which was far more intensive and fruitful than in most paper sessions. Some of the issues raised in the discussion were:

- the importance of oral and/or written reports, since communicating the results of any design project to the customer and/or boss is essential,
- the importance of actually making something, traded off against the very great investment of time this usually requires,
- the contrast between "real" and contrived projects—in manageability, in motivation, and in impact on learning.
- How large a role should a project play in a student's academic program? The examples ranged from single-semester courses, through the major program at Massachusetts.
- Should students start with a faculty-prepared "proposal," or should preparation of the proposal from an initial, vaguely-formulated problem statement, be an

essential part of the project course? (Both sides of this were well represented.)

While none of these questions, or any of the others raised during the two sessions, could truly be "resolved," much value was derived through exchange of ideas and concepts, by the authors and by members of the audience, relative to both the idea of using projects in undergraduate engineering education, and the several different project concepts presented. There was fairly general agreement on a number of points, including:

- Engineering students need to learn the basic principles of engineering science.
- Engineering students need an opportunity to apply these principles.
- The best way to apply these principles is through involvement in at least one design project.
- Design projects help to develop in students an understanding of design methodology, an integration of basic principles, and recognition of various concepts (e.g., economics, personal relationships, and communication) which are important to accomplishing projects but are not always taught in the classroom.
- Project involvement is an important part of preparing a graduate to function effectively in the working world of engineering design.

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How Well Does Design Education Prepare People for Industry?

The Design Engineering Division's Design Education Committee sponsored a two-session Panel at the 1980 Winter Annual Meeting on the subject, "How Well Does Design Education Prepare People for Industry?". Our goal in putting together this panel discussion was to exhibit some of the different approaches presently being used to teach mechanical engineering design, and then to elicit comparison and evaluation of the different approaches discussed (and others, if possible).

We attempted to achieve these goals by first having faculty from several Mechanical Engineering departments employing distinctly different approaches to teaching design describe their programs. We planned to then provide some level of comparison and evaluation by having recent graduates of the same programs talk about how they perceive that their educations prepared them to enter industry as design engineers. The final step, tying it all together, was to encourage an extended, free-flowing discussion among the speakers and the audience.

We did this at the Winter Annual Meeting at the Conrad Hilton in November 1980. The Committee sponsored a pair of sessions, with three schools and about a half-hour discussion in the morning (for those in the audience who could not return for the afternoon session), and two more schools plus an extended discussion after lunch. How well we succeeded was shown in part by the large number of WAM attendees who showed up in the morning. Sixty-one people turned in attendance cards, including 47 faculty members, 12 people from industry, and a pair of government employees. We quickly overflowed our rather small room, and executed a hasty move to a room which was being held for a luncheon.

The five programs which were presented were different, and were well showcased by the faculty panelists. The "recent graduates" were perhaps too recent in some cases, being graduate students rather than working designers with some experience. The presentations were good, and the discussion was very spirited. As hoped, discussion participants expressed thoughts on the programs presented and on others. A further indication of the success of the program is that many of the morning sesson audience returned for the afternoon session.

Morning Program. The morning session featured the Massachusetts Institute of Technology, Stanford University, and the University of California at Berkeley.

MIT was represented by associate Professor Woodie Flowers, and John Csuri, BS '76, a member of the Technical Staff at Bell Laboratories (who also received his MS in the Stanford program described in the same session).

Professor Flowers spoke about MIT's commitment to teaching design through first-hand experience. Emphasis is placed on creative projects that stretch the students' capabilities while teaching them to recognize and work within a set of appropriate and often subtle constraints. These projects were described at greater length by Professor Warren Seering at the 1979 Winter Annual Meeting Session on the role of projects in teaching mechanical design (see Notes elsewhere in this Volume). The most well known of these projects requires the design and construction of a machine to execute a simple, well-defined task from a package of raw materials which is provided to each student. This project culminates in a head-to-head competition between the students' machines to determine the most successful design. John Csuri (who had been out of MIT for 4 1/2 years, including one year of graduate study) said that he remembered little of the specific content of his MIT courses; what had stuck in his mind were the design projects. John said that "education" in basic disciplines does not seem to be sufficient; one needs also to be "trained" in the design process and design skills in order to become a working design engineer. In his first job assignment, he was given a design to carry out, and this training in drawing on "all of the past to do something new" really paid off.

Stanford's ME Design Division's story was told by Associate Professor Larry Leifer and Rick Epstein, MS '80, Senior Developmental Engineer at Baxter-Travenol Labs.

Professor Leifer described three tracks available for the Mechanical Engineering Design student at Stanford:

- a "traditional" ME program, with design-oriented courses;
- a combined ME and Industrial Design program; and
- their unique (graduate) Design Division program, which has an intensive project focus.

Among the outstanding elements of this last program are outside sponsorship (with both funding and personnel interaction) of the projects, and an emphasis on the design of "smart" (microprocessor-controlled) products.

Epstein described the project in which he had been involved: the design of a motorized wheelchair for the quadriplegics, the movement of which is controlled by the rider's head position and motion. This project won for Epstein and his partners second prize in the James F. Lincoln Arc Welding Foundation Student Design Contest, and was also the subject of a paper presented at the 1981 Design Engineering Conference.

The University of California at Berkeley faculty representative was Assistant Professor David Dornfeld; he was supported by Gary Fasola, a member of the Technical Staff at Hughes Aircraft, who is completing his MS at Berkeley.

Dornfeld described Berkeley's extensive coursework offerings in Mechanical Engineering Design. Mr. Fasola supported Professor Dornfeld's statements, citing the "high caliber of many technical courses, . . . supported with project engineering courses." From the extensive course selection, he was able to create a study program emphasizing manufacturing engineering. A Case Studies course and a Project Engineering course tied together the material from the rest of the program. Another aspect of his Berkeley education which was very important to Fasola was the chance to participate in a cooperative work-study program.

Afternoon Program. The presentations were completed in the afternoon by representatives of Worcester Polytechnic Institute and Carnegie-Mellon University.

From *Carnegie-Mellon University* were Professor Dwight Baumann and Dr. Fritz Faulhaber, PhD '79, president of the American operations of a high-technology family industry.

Professor Baumann has been working closely with the faculty of Carnegie-Mellon's Graduate School of Industrial Administration on a program focusing on entrepreneurship. Faulhaber, a recent PhD student of his, discussed his experiences in graduate school, especially his interactions with many Masters candidates who worked on parts of the design project (a microprocessor-controlled taxi meter system) which was the core of Fritz's dissertation work.

Worcester Polytechnic Institute was ably represented by ASME past-president, Professor Donald N. Zwiep, Head of the Mechanical Engineering Department, and John Caola, a graduate student.

Zwiep described Worcester Polytech's unique nontraditional educational plan, based upon a "performance-based, time-independent program of study." In order to graduate from WPI, a student must complete

- a project in a major field;
- a project relating science and technology to societal concerns and human needs;
- a minor in an area of humanities; and
- a competency exam in the major field.

The competency exam, which may last a week, consists of a single, major problem (in the solution of which any resources may be used) and an oral exam on the "how" and "why" of the solution to the problem. Typically, 60 percent of students successfully pass the competency exam the first time they take it.

The central concept of the program is that "students are required to demonstrate that they can learn on their own, translate learning into an understanding of societal needs, and be thoroughly aware of the interrelationships among basic knowledge, technological advances, and human need." In preparation for their projects and exams, WPI students take a mixture of traditional engineering-science courses (laced with design concepts), one or two design courses, and some amount of independent study. The program is faculty intensive, requiring much close contact between students and teachers.

John Caola's reaction to his undergraduate program was that it forced him to learn on his own, and taught him how to approach an unknown problem—or, rather, the program let him discover for himself how to do it.

Discussion. There was especially spirited discussion at the end of the morning session, prompted by a group of pointed questions asked by faculty members in the audience who had identified some relationships between things they were doing (or being kept from doing) and the panelists' presentations. Mechanical engineering instructors contended that many of the project-oriented activities at various institutions were not practical in the face of limited time in the curriculum, limited funding for expendable supplies, and, most notably, the limited recognition given to design professors seeking tenure. This last, they argued, is a special concern since in most institutions tenure can be achieved only by independent, quality research performed in a "traditional" engineering specialty, often unrelated to design. In addition, project-based design activities are faculty-intensive—difficult to undertake with increased enrollments and reduced faculty size at many schools.

The afternoon discussion took a different tack, with several visitors seeking advice from both the panel and the audience on successful project-based educational experiences. An argument, which at one point became rather heated, erupted over the issue of curriculum completeness, with some experienced engineers marveling over students' ability to graduate without having completed formal courses in such traditional mechanical engineering staples as heat transfer.

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