Enhancement of Faculty Design Capabilities

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Abstract

A crucial factor affecting U. S. productivity is the decline in the quality of engineering design. The response of the Accreditation Board for Engineering and Technology to the pressures to strengthen undergraduate design requirements has not only not improved design education significantly, but has resulted in more programs not meeting the established standards. Vital to the strengthening of the design requirement is the improvement of faculty design capabilities. The two-week workshop on Enhancement of Faculty Design Capabilities held at Southern Methodist University from July31 -August 10, 1995 is part of a three-year plan for enhancing engineering design skills of faculty from all engineering disciplines. Engineering faculty participating in this workshop developed and documented 70 design exercises for use in the engineering sciences: mechanics of solids, electrical theory, fluid mechanics, and transfer and rate mechanisms. A significant number of these exercises were developed for introduction into the first year course with the potential for follow-on activities in the engineering science courses. Emphasis was placed on developing design materials which could be integrated throughout the engineering curriculum and which were easily transportable to engineering programs at other institutions.

The Need for Improving Design Education

There is a widely held perception that U. S. industry's extended period of world dominance in product development, manufacturing innovation, process engineering, and productivity has ended. The relative decline of U. S. productivity and competitiveness can be attributed to several factors, including national fiscal policies, exchange rates, international labor rates, deficiencies in manufacturing, industrial management and accounting practices, unfair labor practices, and methods of generating capital.

A crucial factor that is often overlooked is the decline in the quality of engineering design in U. S. industry. Engineering design is the crucial component in the product realization process, the means by which new products are conceived, developed, and brought to market. It has been estimated that 70% or more of the life cycle costs of a product are determined during design.

Unfortunately, the overall quality of engineering design and engineering design education in the United States is inadequate. The National Research Council in its 1991 report[1] "Improving Engineering Design: Designing for Competitive Advantage" includes in its observations:

1. The best engineering design practices are not widely used in U. S. industry.
2. The key role of engineering designers in the product realization process is not well understood by management.
3. Current engineering curricula do not focus on the entire product realization process.
4. Although universities nominally bear responsibility for producing both practices and practitioners, they do not fulfill this role in engineering design in the United States.

Engineering education must include the foundation of successful practice, effective teaching, and relevant research in engineering design. Few curricula consider state-of-the-art design methodologies. Perhaps this is because few engineering faculty practice these methodologies, and so few engineering faculty can teach them.

Strong improvement in engineering design teaching is unlikely without strong, knowledgeable, enthusiastic faculty who interact with a broad base of colleagues in industry as well as academe. This faculty must be encouraged to obtain an educational background in teaching design, develop industrial experience, and develop and maintain contacts with industry.

Previous Efforts at Improving Design Education

Professional engineering societies have often provided the leadership in improving engineering education, largely through the Accreditation Board for Engineering and Technology (ABET). ABET has steadily strengthened the design requirement during the past decade in response to the professional engineering societies and industry[2].

The Design in Engineering Education Division (DEED) of the American Society for Engineering Education has been a strong proponent of engineering design education since the 1960's through sponsorship of design education workshops for engineering educators from all engineering disciplines. DEED continues to support the Engineering Case Library[3] which evolved from the Engineering Case Program originated at Stanford University in 1964.

The Sloan Foundation in the 1950's and 1960's funded many of the strongest engineering design programs that continue at institutions such as Worcester Polytechnic Institute and Drexel University. The Sloan Foundation was a founding supporter of six Engineering Design and Design Education Conferences held in alternative years between 1963 and 19734. During the 1960's and 1970's many of the local design programs published compendiums of student senior design projects. A large number of these senior design projects were collected nationally into the Design Projects Digest edited by Parke and Heinsohn[5].

In recent years, the National Science Foundation and other federal agencies have provided funding for design and design education workshops, conferences, and coalitions[6-8]. Engineering technical societies have encouraged design opportunities among undergraduates by sponsoring design projects and contests. Many of the professional technical societies sponsor design competitions as an aid to engineering instruction in design. All of these design competitions are directed to faculty teaching design courses and provide little help for engineering faculty in engineering science courses. None teach the basics of design, except as specifically directed toward completion of the project competition.

Recent ABET Pressures

The response of ABET to the pressures of the technical societies to strengthen the undergraduate design requirements has not improved design education significantly, but has resulted in more engineering programs not meeting the established standards. ABET annual reports show that deficiencies in engineering design are one of the leading causes of less-than-favorable accreditation actions. Each year 60% or more of the engineering programs evaluated receive less-than-favorable accreditation actions.

Several factors contribute to the deficiency in engineering design. While some of the design deficiencies are due to a lack of a "capstone experience", the capstone experience has received most of the attention of faculty and is likely the most understood aspect of the design requirement. Many of the design deficiencies come from the tendency of engineering faculty to include design requirements in a few of the courses in the junior-senior level. Much of this "design content" is in fact analysis.

The greatest deficiency occurs because design is not integrated throughout the engineering science courses from the first year to the senior year. This area is also where the least attention has been paid because many of the faculty in these courses have little industrial and/or engineering design experience. The NSF supported workshop described here is a response to the engineering design deficiencies in this last area.

NSF Summer Workshop: Enhancement of Faculty Design Capabilities

The summer workshop is part of a three-year plan for enhancing engineering design skills of faculty from all engineering disciplines. The total project is to develop and offer a two-week workshop at Southern Methodist University each summer, for three consecutive summers. The third year will also include a National Conference on Engineering Design Education. This will form a strong data base of information on how to teach and implement design modules and programs at other engineering institutions. A key component of the project is a follow-up program to insure dissemination of design modules and other materials developed by participants to other institutions. This paper reports on the results of the first two-week workshop held at SMU from July 30 - August 11, 1995.

Workshop Goals

Young faculty are pressured into abandoning design in favor of research to obtain tenure. The resulting difficulty is that most faculty have little understanding and experience in the engineering design process, and less experience in integrating the engineering design process into their classroom teaching. This workshop was to provide engineering faculty with the knowledge, tools, and experience to improve their engineering design teaching capabilities through intense immersion in a two-week summer workshop and a follow-up program during the academic year.

There were three goals for this project. The primary goal was to increase the number of qualified engineering faculty who are able to teach engineering design, with special emphasis directed at attracting and educating faculty who teach primarily non-design, or engineering science, courses in two-year and four-year institutions.

The second goal was to develop methods for disseminating design materials, design methodologies, and design philosophies developed by participants to as many faculty as possible at the home institutions, and at other institutions. The third goal was to create a network of engineering faculty who can communicate and interact on engineering design issues across disciplinary and institutional lines.

Disciplinary Focused Topics

A multi-activity program provided participants with information and experience in the areas of Design Methodology, Design Content, Design Constraints, Design Tools, and Teaching Design.

Design Methodology. The overall product realization process was emphasized with consideration of the following design features: establishing needs, objectives and criteria, formulating design problem statements and specifications, consideration of alternative solutions, feasibility considerations, production / construction processes, and detailed system descriptions. Currently employed product realization processes such as Polaroid's Product Delivery Process and Hewlett-Packard's Phase Review Process were introduced. A survey of different design methodologies, including the Systematic Approach[9], the Axiomatic Approach[10], and design as practiced in Germany, England, Russia and Japan was included.

Design Content. Relevance of content material to modern design procedures was central to discussions of topics which included statistics and probabilistic design, fault tree analysis, design of experiments, quality and quality function deployment, and other topics.

Design Constraints. Design constraints associated with intellectual property, regulatory agencies, economics, safety and health, reliability, aesthetics and social responsibility were considered in achieving problem solutions.

Design Tools. New tools to improve designer productivity or performance such as CAD, optimization, statistical methods for achieving robustness, and analysis and simulation were discussed.

Teaching (Coaching / Mentoring) Design. Teaching methodology and tools useful to teaching engineering design, including developing a Design Plan, building a student Portfolio, team-building, posing problems in the natural context, and design by memo were included in discussions.

Workshop Participants

The general target-group was engineering faculty from all engineering disciplines. Engineering faculty currently teaching non-design engineering courses were specifically targeted. However, a small number of the participants were experienced engineering design teachers who provided a perspective different from that of the authors. A national recruitment effort included program descriptions in national publications, direct mailings, and liaison with national and regional organizations which focus on engineering education, with special efforts to recruit women engineering faculty, minority engineering faculty, and individuals with disabilities. Each applicant submitted a two page resume, a letter of support by the faculty member's immediate administrator, a current design plan for their program, and a preliminary plan for involving other faculty at their home institution. Multidisciplinary faculty teams from an institution were encouraged.

The sixteen faculty selected to participate in the workshop represented 13 four-year institutions with engineering programs and one four- year institution with engineering technology programs. Faculty represented 3 civil engineering programs, 5 electrical engineering programs, and 8 mechanical engineering programs. One institution sent a multidisciplinary faculty team with one member from each of the three engineering disciplines. Four faculty had been teaching for less than 6 years, seven had taught between 6 and 20 years, and five faculty had taught more than 20 years.

Workshop Format

. The workshop used a format which included a combination of lectures, discussion sessions, and work sessions to impart design material and to involve faculty in the design experience.

Lectures. Lectures were presented by the authors primarily to impart knowledge, information, and techniques. Two industry speakers from Texas Instruments Inc. presented their views of "What Industry is Looking for in a Recent Graduate. " Dr. Terry Baughn from the Defense and System Engineering Group presented the viewpoint of the mechanical design engineer working in defense work, and Dr. John Provence from the Semiconductor Division presented the viewpoint of the electrical design engineer working in commercial products.

Discussion Sessions. The engineering and classroom experiences of the participants were valuable contributions to general discussion sessions. These sessions encouraged a free exchange of information, viewpoints, and experiences. Questions relevant to engineering, design, and teaching were raised/ debated/ answered in these sessions.

Work Sessions. Time was reserved for participants to work on projects. These sessions provided participants with the opportunity to develop, modify, and finalize design materials in the form of design problems, design projects, and case studies.

Workshop Output

Workshop participants applied new information and methodologies encountered during the workshop to development of a compendium of 70 design problems/ projects. Participating faculty generated design exercises as a team, with initial efforts achieved with the entire group participating. Later the faculty were divided into engineering science working groups.

First Exercise. Participating faculty were given the assignment of developing two ideas for a design project to be introduced in the first year class but which could be continued in later courses downstream in the curriculum. The first part of the assignment was to develop an <u>individual</u> design project which could be accomplished in the first year course. The second part of the assignment was to develop a <u>team p</u>roject for the first year course.

Each participant presented his / her ideas to the group in a design review format, with the participating faculty constructively suggesting improvements to the presented idea. Following the review process, the faculty member modified and improved the design exercise and documented the project for a formal review of hardcopy material by the group. Each exercise was copied and distributed to all members of the group for additional review and comments. These reviews were used by the author to make final changes. Initial efforts in the first year exercise produced 36 projects: 16 design problems requiring individual student work effort and 20 design problems requiring student team work effort.

Second Exercise. The participating faculty were given the opportunity to sign-up for a working group in each of the engineering science areas as defined by the Grinter Report[11]:

- Mechanics of Solids (statics, dynamics, and strength of materials)
- Fluid mechanics
- Thermodynamics
- Transfer and rate mechanisms (heat, mass, and momentum transfer)
- Electrical theory (fields, circuits, and electronics)
- Nature and properties of materials (relating particle and aggregate structure to properties)

Most faculty signed up for several of the working groups. These working groups were scheduled to meet during the day to generate project material, to critique and improve the material, and to document the design material. Thirty-four design problems were generated and documented in these areas.

Dissemination Efforts

A compendium of 7(I design exercises has been created. This compendium is available in hardcopy and on floppy disk for the PC. The intent of the compendium is to encourage engineering science instructors to use the design exercises in the following areas to increase design content in their courses without expending major effort, reorganizing courses, or displacing material.

First year - individual work effort	16
First year - team work effort	20
Dynamics	4
Electrical theory	9
Fluid mechanics	2
Heat transfer	6
Strength of materials	4
Statics	9

The design exercises developed are presented in a three page format: the summary page, the student assignment, and engineering notes. The user of these materials can contact the contributor of the exercise for additional material or experiential guidance on the use of the exercise. Similarly, the contributor would welcome feedback on this material so that the material maybe improved.

Summary Page. The summary page contains a narrative presenting a brief overview of the design exercise, the type of design activity, the suggested length of the student assignment, and the location of the student work. Details of the design work are presented through a list of ABET descriptors which identify the engineering science content, the type of design, the elements of design, the features of design, the realistic constraints, and the type of student work effort. Finally, information on the contributor of the exercise is presented so that the user may contact the developer of the material.

Student Assignment. A narrative describes the design exercise. This narrative should be directly transportable to the classroom. In some cases the user may wish to customize dates and names for use at his/her institution. Narratives which place the design work in a natural context or setting are presented in several formats.

Engineering Notes. Engineering notes are presented as an aid to the instructor. These may be helpful in identifying resource requirements before assigning the design exercise, or they may contain suggestions on several ways to present the problem to the students.

Follow-up Activities

There is ongoing assessment of participant's experiences with the materials developed during the workshop and incorporated into courses at their home institutions. Participants working on similar materials are communicating results and experiences via electronic mail and hard copy. Follow-up activities are in progress to assess the involvement of other Faculty at the home institution and the development of a new design plan for the engineering program at the home institution.

Future Efforts

Planning is underway for a second workshop on the SMU campus during the summer of 1996 as a result of continued funding by NSF. Participants in this workshop will add to the compendium of design exercises developed in the 1995 workshop. Planning will begin in spring of 1996 for the National Conference on Engineering Design Education to be held in Dallas, Texas in the spring of 1997. Pending allocation of funds to NSF for 1997, the third summer workshop will be held at SMU in summer of 1997.

Acknowledgments

This manuscript and the workshop described in the manuscript were developed under DUE-9455062 grant from the National Science Foundation, Division of Undergraduate Education, in the Directorate for Education and Human Resources. The authors wish to express their gratitude to the following contributors to the design compendium: Luis Bocanegra, University of Puerto Rico; Charles P. Callis, University of Tennessee at Martin; Theodore Comstock, University of Tennessee at Martin; James N. Craddock, Southern Illinois University at Carbondale; Charles E. Fosha, Jr., University of Colorado at Colorado Springs; Kenneth French, John Brown University; Prasad Gavankar, Texas A&M University-Kingsville; Donald F. Hanson, University of Mississippi; Rob Jarman, University of Technology, Sydney, Australia; Roy C. Johnston, McNeese State University; Mary L. McAllister, Western Carolina University; Robert A. McLauchlan, Texas A&M University-Kingsville; Saeed Niku, California Polytechnic State University-San Luis Obispo; Lisa A. Riedle, University of Wisconsin-Platteville; William W. Steffenhagen, Saint Martin's College; David Yang, University of Tennessee at Martin.

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8. SUCCEED Coalition, a partnership of Howard, CCNY, Maryland, MIT, Morgan State, Penn State. and Washington.