

# Challenges in Curriculum Renewal\*

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*While a wide spectrum of stakeholders in engineering education have called for accelerating the pace and substance of curriculum renewal, many challenges to reform exist. Advancing effective curriculum renewal requires a combination of well-articulated goals, faculty and administrative leadership, resources and the continuous evaluation of progress. Efforts to implement a curriculum focused on developing world class engineers are described. Evaluations of the impact of the changes in the curriculum on student perceptions of their educational experiences focused on world class engineer goals are discussed.*

## INTRODUCTION

IN THE PAST decade, calls for engineering curriculum renewal have been made from both inside and outside the university community. In these calls for reform, a number of issues are cited, including the rapid technological advances in the engineering disciplines, the necessity to attract strong and diverse groups into the engineering profession and the realization that engineering is practiced in a global environment [1]. Curriculum renewal efforts have been supported by the National Science Foundation, which established a set of coalitions to undertake significant change in undergraduate engineering education and followed up with program support for systematic reform in engineering education and with the establishment of a national center focused on engineering education [2]. The National Academy of Engineering has also established a center to support the renewal of engineering education [3].

Many of the calls for reform from outside the engineering education community have focused primarily on issues related to the attitudes and skills required to prepare engineers generally for the profession, such as communication skills, teamwork, lifelong learning and ethics. The efforts to strengthen the role of attitudes and skills in engineering curricula have been supported by changes in the ABET accreditation criteria [4].

These efforts have also been supported by initiatives to change the learning environment in which engineering is taught and to rely less on traditional lecture formats and increasingly on the creative aspects of engineering using active learning and problem-based learning to more effectively engage students.

Many of these reforms and renewal efforts suggest that curricula transformations are needed to graduate engineers who can be leaders in the global economy. In short, one might say that many

of these are directed toward producing ‘world class engineers.’

## CHALLENGES TO EFFECTING RENEWAL

Curriculum changes focused on introducing educational experiences to develop attitudes and skills in concert with disciplinary oriented scientific and technical knowledge are difficult to effect:

- Curriculum changes related to attitudes and skills are more difficult to define than disciplinary knowledge based materials and to identify in terms of measurable outcomes.
- Curriculum changes related to attitudes and skills are most effectively learned as integral parts of disciplinary subject matter; thus, integration is required and an overall curriculum design and holistic approach to delivery is required.
- Not all faculty are well prepared to accept the additional responsibility of implementing the teaching of attitudes and skills coupled with disciplinary knowledge and many programs are not prepared to create and implement a fully integrated program.
- Even drawing on the results of educational psychologists, it is difficult to assess success in curriculum renewal, particularly with respect to changes that try to influence attitudes and skills which may impact engineers’ effectiveness over a long-time horizon.

## A PROCESS FOR CURRICULUM RENEWAL

While these challenges have provided significant impediments to wide-scale curriculum renewal, some notable examples exist of programs which have started to develop a holistic curriculum, including efforts at the Olin College, Drexel, Rose Hulman, Harvey Mudd and a number of others that have made particularly strong advances

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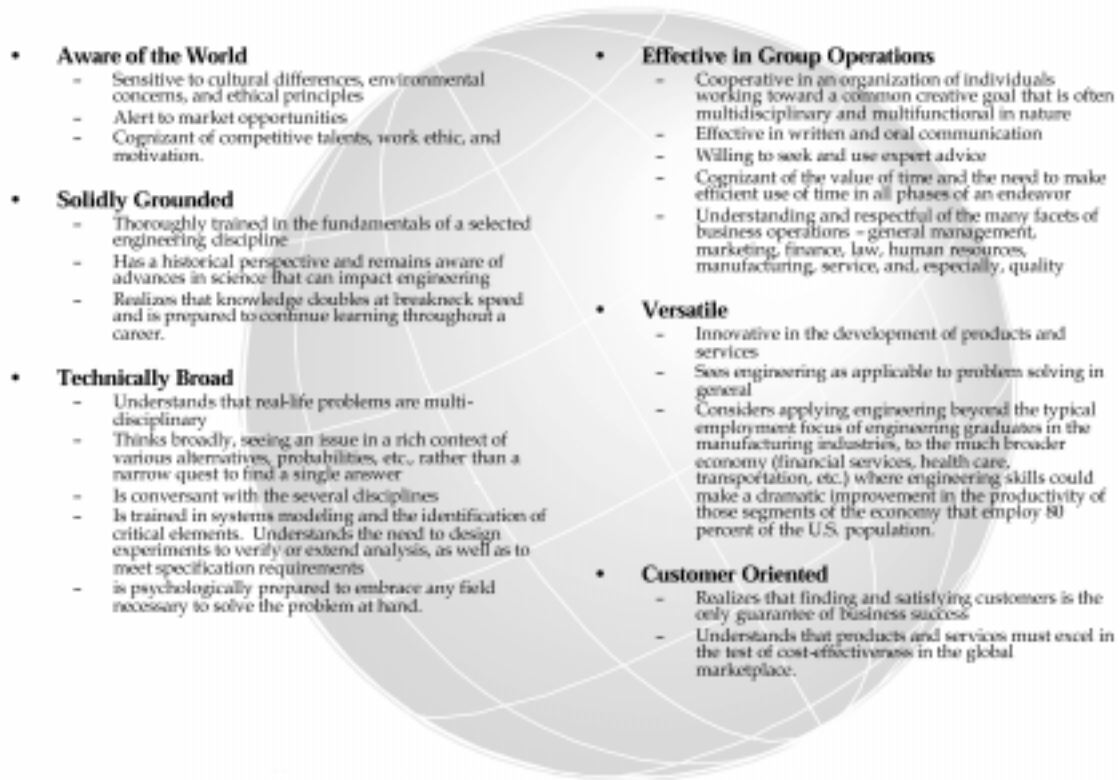


Fig. 1. World class engineers.

in design-related aspects of the engineering curriculum. Much can be learned from these initiatives and the barriers they have overcome. Identifying and building on these successes is one of the objectives of the NSF-supported Center for the Advancement of Engineering Education at the University of Washington [2].

While the process for curriculum renewal may have many variations, to accomplish significant renewal many of the efforts cited above had a number of common elements which may include:

- well-articulated goals;
- committed faculty and administrative leadership;
- a central focal point, such as an education center or institute;
- resources to support effort;
- definition of ways to measure progress; and
- recognition for successful efforts.

These elements have been integral to successful efforts undertaken in many universities and are illustrated in the following section using the efforts at Penn State as an example.

## WORLD CLASS ENGINEER

To help guide the efforts to renew the engineering curriculum at Penn State, the concept of the 'World Class Engineer' has been developed in cooperation with the Leonhard Center Advisory

Board<sup>1</sup>, which consists of industrial and business professionals. The qualities identified by the advisory board for a world class engineer are summarized in Fig. 1. The attributes build on the basis of a solidly grounded, technically broad, versatile engineer who is aware of the wider world, effective in group operations and customer-oriented. The world class engineer concept is based on the growing globalization of engineering and the increasing necessity for successful engineers to be able to communicate effectively, to work in teams, engage in lifelong learning and have a solid foundation in ethics.

The world class engineering attributes have served for the past six years as a unifying theme for curriculum renewal. The process of curriculum renewal has been aided by having a set of goals which clearly relate to many of the external constituents of engineering education as well as to both faculty and students. The attributes are also consistent with the most recent general criteria defined by ABET.

The process of curriculum reform has been facilitated by a faculty advisory committee to the Leonhard Center and by fully engaging department heads in curriculum renewal activities. Additionally, the process has been facilitated by focused departmental initiatives to achieve the world class

<sup>1</sup>The Leonhard Center was created in 1991 by an endowment from William and Wyllis Leonhard for the enhancement of engineering education at Penn State University.

engineer goals and supported by gifts from alumni. Thus, having a clear set of educational goals, having a focal point for educational renewal, engaging faculty and faculty leadership in the process, and having key initiatives supported through external funds have all been instrumental in helping to facilitate curriculum renewal.

Changes to the overall engineering curriculum which support world class engineering graduates have included:

- Incorporating early in the curriculum design experiences which integrate the concepts of the world class engineer: first-year seminars and design subjects incorporating the complete engineering design process from conception to prototype and evaluation with students working in teams and communicating both internally and to external constituents.
- Development of the Learning Factory, where students design, build and evaluate devices as part of senior level projects which are defined and supported by industry.
- Establishment of a global engineering partnership program with international universities and companies for joint student design projects and internships.
- Introduction of Engineering Projects and Service to the Community (EPICS), which engages teams of students to undertake projects defined and needed by the community.
- Development of the Leadership Development and Entrepreneurship Minors, which engages students in the practices of leadership and entrepreneurship.
- The development of ethics modules to assist college faculty in introducing ethics into their disciplinary oriented subjects.

Many changes which have been implemented in individual disciplinary curricula have also occurred, including:

- Development of IME Inc., a product development effort that spans the curriculum in industrial and manufacturing engineering from the early years to the senior year and provides an integrated longitudinal experience for students in developing, manufacturing and marketing a product.
- Development of the 'Sailplane' Project in Aerospace Engineering, in which students in the department have an integrated project experience, spanning from their first year to graduation, working in teams to develop an integrated set of experiences with increasing complexity as they gain maturity.
- The development and utilization of case studies in Civil and Environmental Engineering to illustrate the business and ethical aspects of professional engineering practice.
- Creation of IDEALS by the Department of Mechanical and Nuclear Engineering, featuring integrated design, experimentation, analysis and life skills.
- Developing a problem-based learning approach in introductory engineering dynamics by the Engineering Science and Mechanics Department.

These efforts have affected the core aspects of disciplinary curricula and complement the changes made in the early, formative years as well as in the senior years.

### ASSESSING THE IMPACT OF CURRICULUM RENEWAL

One of the most difficult aspects of changing the engineering curriculum, especially with the multifaceted goals embodied by the 'world class engineer', is assessing the impact of curricula change. To gain insight into these aspects of change, for the

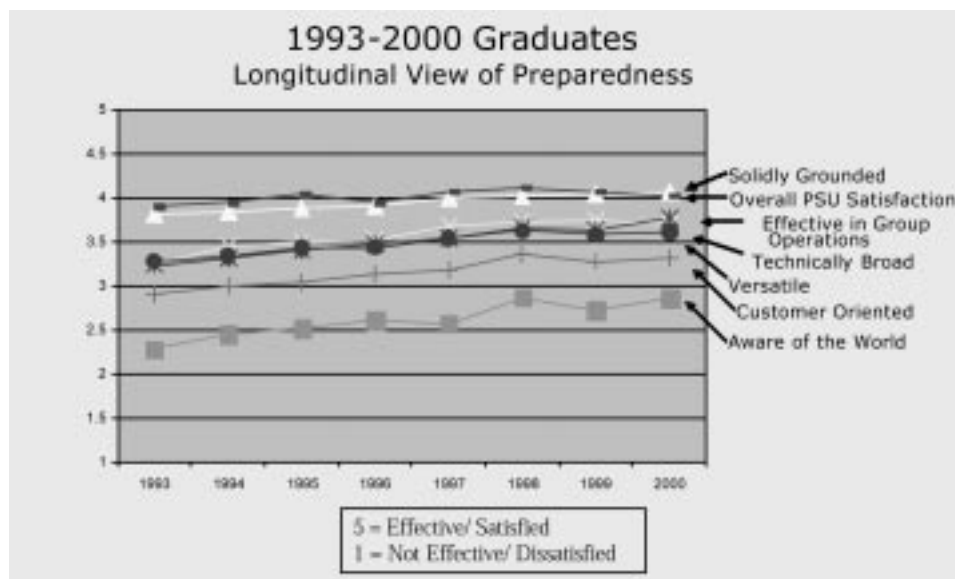


Fig. 2. Alumni survey results in the context of world class engineer attributes.

past eight years surveys have been conducted of graduates with two to three years of experience to determine how they view their educational experience. The results of these surveys are summarized in Fig. 2, where each of the attributes of the world class engineer have been assessed with respect to their effectiveness in the curriculum.

In Fig. 2, over the five years of the survey, graduates have indicated that:

- They are consistently solidly grounded in their scientific and technical disciplines.
- They are increasingly well prepared in technical breadth, versatility, teamwork and customer orientation.
- They are least well prepared in being made aware of the world, but some progress is being made in this area.

These types of data help to identify both successes and gaps in the effectiveness of implementing curriculum reforms focused on world class engineers. They have provided essential metrics in determining whether these 'professional attitude and skill based characteristics' are being effectively integrated into the curriculum and having an impact on students who are practicing engineers.

## SUMMARY

Curriculum reform to produce the engineers needed in the future—world class engineers—is difficult to achieve and to measure. The fact that many of the attributes are skill and attitude related and require integration into the scientific and technical disciplinary material represents a further challenge to implementation.

The curricula renewal process can be facilitated significantly by engaging external advisory groups, providing a focal point of renewal effort through centers and institutes, truly engaging faculty and departmental leadership, developing external resources to support renewal efforts and by measuring and responding to the impact of changes with time.

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**David N. Wormley** was appointed Dean of Engineering at Penn State in July of 1992. Prior to his appointment, he served as Associate Dean of Engineering (1991–1992) and Head of the Department of Mechanical Engineering (1982–1991) at the Massachusetts Institute of Technology. Professor Wormley's research is in Dynamic Systems and Control with applications to transportation systems, fossil fuel power plants, and fluid power systems. At MIT, he founded the Association of American Railroads affiliated laboratory and co-founded the Vehicle Dynamics Laboratory. He has supervised 23 Ph.D.s and 72 Master's research theses, written more than 100 papers and reports and co-authored the textbook *System Dynamics: An Introduction*. Dr Wormley has served as Vice President of the Systems and Design Group of the American Society of Mechanical Engineers, been a member of the editorial boards of the *International Journal of Engineering Education* and *The International Journal of Vehicle System Dynamics*, and is a member of the educational advisory committee of the National Society of Professional Engineers. He was chair of the National Science Foundation Engineering Directorate Advisory Committee and of the Executive Committee of the National Research Council Transportation Research Board, and is currently chair of the ASEE Engineering Deans Council. Dr Wormley is a member of the American Society of Engineering Education and is a Fellow of the American Society of Mechanical Engineers. He received the Dynamic Systems and Control Division of the American Society of Mechanical Engineers Education Award. He also has received a NASA Certificate of Recognition and has twice received graduate student teaching awards from the MIT Department of Mechanical Engineering.