ENGINEERINGCHANGE

A Study of the Impact of EC2000

Executive Summary

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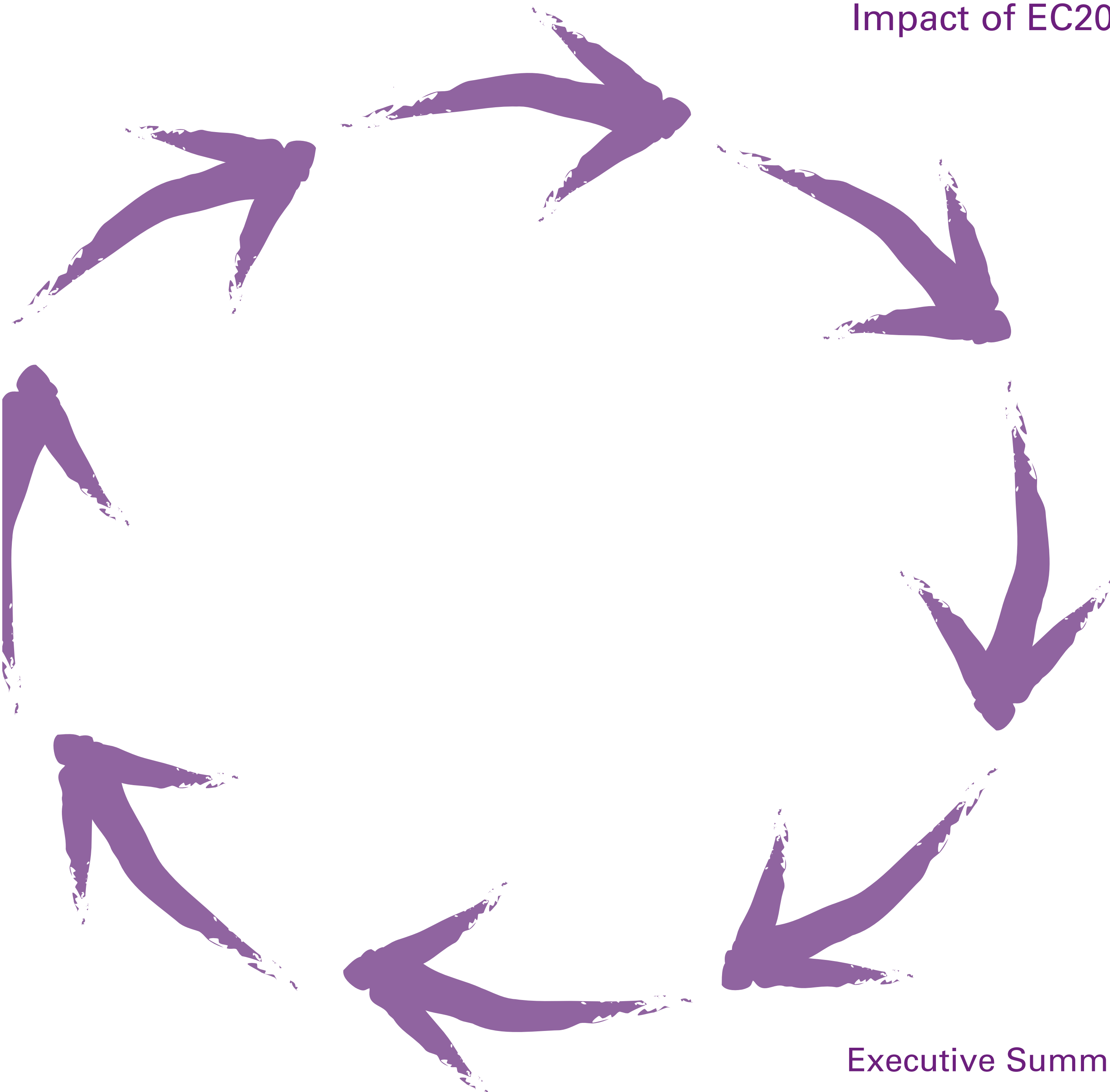

Executive Summary

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Acknowledgements

A study of this complexity and magnitude requires the assistance of a large number of organizations and individuals. We wish to acknowledge the many and important contributions of the following to the success of this study:

- The 28 professional and technical societies that constitute ABET, Inc., and thus supported this study.
- Those societies representing the seven disciplines on which this study focused, for their endorsements and assistance, and their members who responded to the survey of engineering employers: The American Institute of Aeronautics and Astronautics, the American Institute of Chemical Engineers, the Institute of Electrical and Electronics Engineers, Inc., the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the Institute of Industrial Engineers.
- The American Society for Engineering Education for access to its engineering program database, which enabled us to identify and specify the study population and develop our sampling design.
- The National Science Foundation for its financial support of portions of our study (NSF Grant No. EEC-9812888).
- The members of our National Advisory Board (see Appendix C) for their sage advice and steady support.
- The deans, department chairs, faculty members, 1994 graduates, and 2004 graduates of the 40 institutions that participated in our study; without their cooperation, this project could not have happened.
- The Penn State College of Engineering faculty members and students, the ABET Industry Advisory Council, and others who assisted us with instrument refinement, pilot testing, and other forms of advice.
- The ABET executive staff members who provided ongoing support, guidance, and autonomy.

We are grateful to all these people and organizations. Without their assistance, the study would have been greatly diminished. We also wish to say it has been a pleasure and honor to participate in the national conversation on quality in engineering education.

Lisa R. Lattuca
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University Park, PA
March 2006

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Engineering Change:
A Study of the Impact of EC2000

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Are post-EC2000 engineering graduates any better prepared to enter the profession than were their pre-EC2000 counterparts of a decade ago? That question is at the heart of this three-year study, titled *Engineering Change: A Study of the Impact of EC2000*.

In 1996, the ABET Board of Directors adopted the new set of standards, called *Engineering Criteria 2000* (EC2000). EC2000 shifted the basis for accreditation from inputs, such as what is taught, to outputs — what is learned. The new criteria specify 11 learning outcomes and require programs to assess and demonstrate their students' achievement in each of those areas. EC2000 retains earlier accreditation standards' emphases on the development of students' mathematical, scientific, and technical knowledge, as well as standards for program faculty and facilities, but it also emphasizes developing other professional skills, such as solving unstructured problems, communicating effectively, and working in teams. In addition, EC2000 stresses awareness of ethical and contextual considerations in engineering.

In 2002, ABET, Inc., commissioned the Center for the Study of Higher Education at Pennsylvania State University to undertake a three-and-a-half-year study to assess whether the implementation of the new EC2000 evaluation criteria is having the intended effects. *Engineering Change: A Study of the Impact of EC2000* was designed to answer two primary questions:

- What impact, if any, has EC2000 had on student learning outcomes in ABET-accredited programs and institutions?

- What impact, if any, has EC2000 had on organizational and educational policies and practices that may have led to improved student learning outcomes?

Origins of EC2000

Since 1932, ABET, Inc., has been the recognized U.S. accreditor of postsecondary degree-granting programs in engineering. ABET currently accredits nearly 2,000 engineering programs at more than 350 institutions.

ABET accreditation requires, among other things, that engineering programs adhere to a set of quality standards called accreditation criteria. For most of the second half of the 20th century, ABET's accreditation criteria dictated all major elements of an accredited engineering program, including program curricula, faculty, and facilities. In the mid-1990s, however, the engineering community collectively began to question the validity of such rigid accreditation requirements. Following a year of intense dialogue within the engineering community, ABET crafted new and unique accreditation criteria for engineering programs. These criteria became known as *Engineering Criteria 2000* or EC2000.

To answer these questions, the Penn State research team examined educational practices in engineering programs and assessed student performance pre- and post-implementation of EC2000. The conceptual model guiding the study (see Figure 1) summarizes the logic of the study's design.

Figure 1. Conceptual Framework for the *Engineering Change* Study

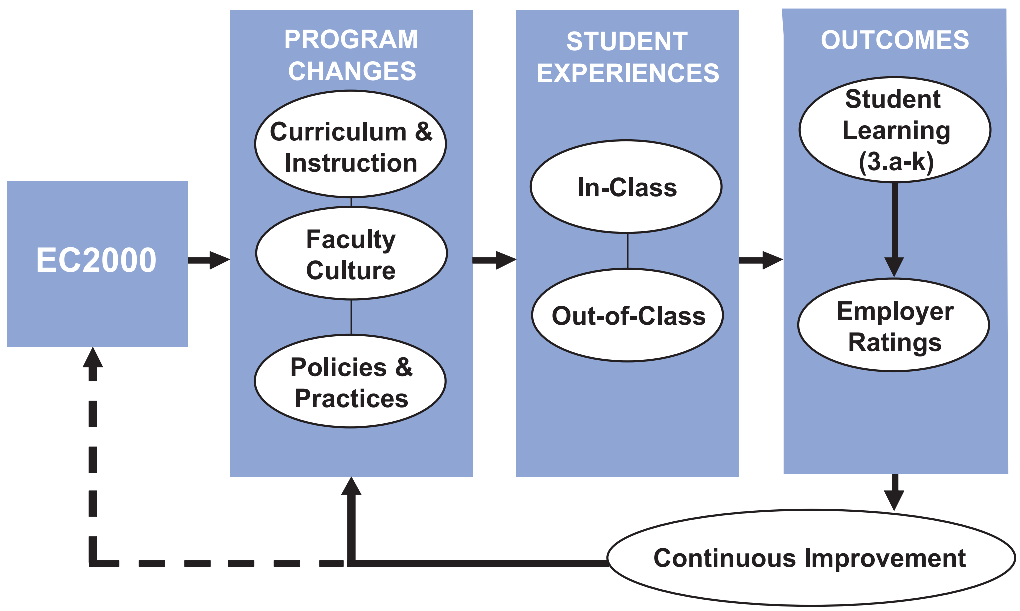


Figure 1 assumes that, if implementation of the EC2000 evaluation criteria is having the desired effect, several changes in engineering programs would be evident:

- Engineering programs would make changes to align their curricula and instructional practices with the 11 learning outcomes specified by EC2000 (Criterion 3.a-k, see Appendix D).

- Alterations in the faculty culture would be evident as faculty members engaged at a higher rate than before EC2000 in activities such as outcomes assessment and curriculum revision.

- Faculty and program administrators would adjust program practices and policies regarding faculty hiring, salary merit increases, tenure, and promotion criteria to give greater recognition to the kinds of teaching and learning required by EC2000.

- All of those program changes would reshape students' educational experiences inside and outside the classroom, which would in turn enhance student learning (defined as improved student performance on measures of the 11 EC2000 learning outcomes).

- Employers would report improvements in the knowledge and competencies of the engineering graduates they have hired since implementation of EC2000.

The EC2000 study evaluated these connections to assess whether any changes in engineering programs and improvements in student learning are a consequence of EC2000 rather than other factors.

Research Design and Sample Selection

The EC2000 study utilized a cross-sectional, pre- and post-EC2000 design that drew on multiple sources of evidence to provide a 360-degree view of the impact of the EC2000 accreditation criteria on the preparation of undergraduates for careers in engineering. Table 1 provides the sample size and response rate for each population studied. By social science standards, the response rates are quite respectable for studies of these populations, and the numbers of respondents provide more than adequate statistical power. [A summary of the study's research design and methods appears in Appendix A.]

Table 1. Response Rates for Target Populations

Data Sources	Target Population	Number of Responses	Response Rate
Programs	203	147	72%
Faculty	2,971	1,243	42%
Deans	40	39	98%
1994 Graduates (Pre-)	13,054	5,494	34%
2004 Graduates (Post-)	12,921	4,330	36%
Employers	unknown	1,622	N/A

Findings from the EC2000 Study

Major findings from the EC2000 study are reported according to the logic of the conceptual model given in Figure 1.

Changes in Engineering Programs

According to program chairs and faculty members, engineering program curricula changed considerably following implementation of the EC2000 criteria. Although few programs reduced their emphasis on the foundational topics in mathematics, basic science, and engineering science, both program chairs and faculty members report increased emphasis on nearly all of the professional skills and knowledge sets associated with EC2000 Criterion 3.a-k. Three-quarters or more of the chairs report moderate or significant increases in their program's emphasis on communication, teamwork, use of modern engineering tools, technical writing, lifelong learning, and engineering design. Similarly, more than half of the faculty respondents report a moderate to

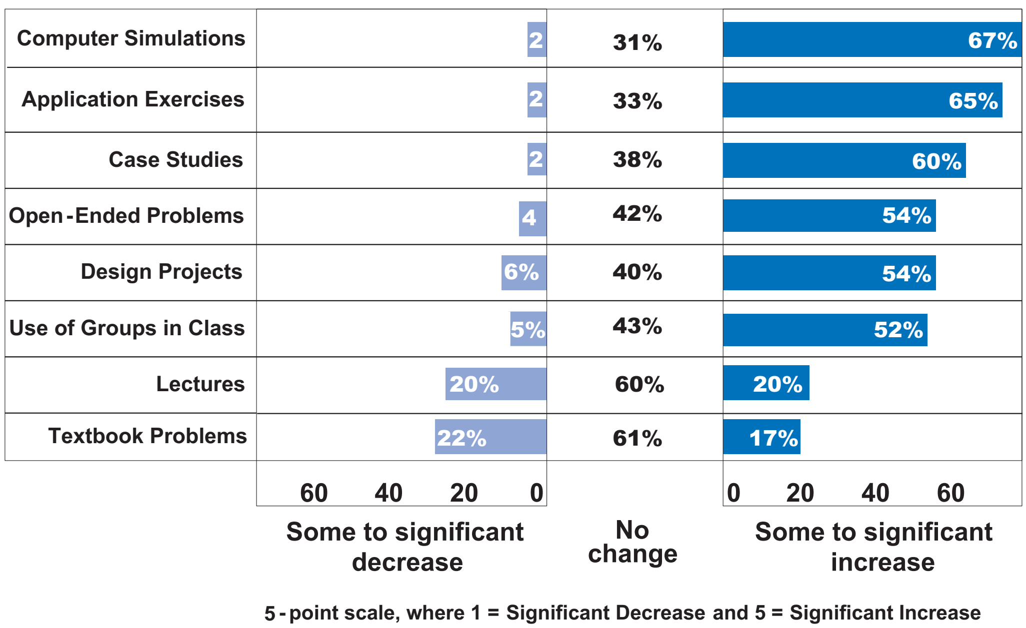
Key Findings: Changes in Engineering Programs

- Greater emphasis on professional skills and active learning after EC2000.
- High levels of faculty support for continuous improvement.
- Mixed emphasis on teaching in faculty reward structure.

significant increase in their emphasis on the use of modern engineering tools, teamwork, and engineering design in a course they taught regularly.

EC2000's focus on professional skills might also be expected to lead to changes in teaching methods as faculty members seek to provide students with opportunities to learn and practice their teamwork, design, and communication skills. Consistent with that expectation, half to two-thirds of the faculty report that they have increased their use of active learning methods, such as group work, design projects, case studies, and application exercises, in a course they teach regularly (See Figure 2).

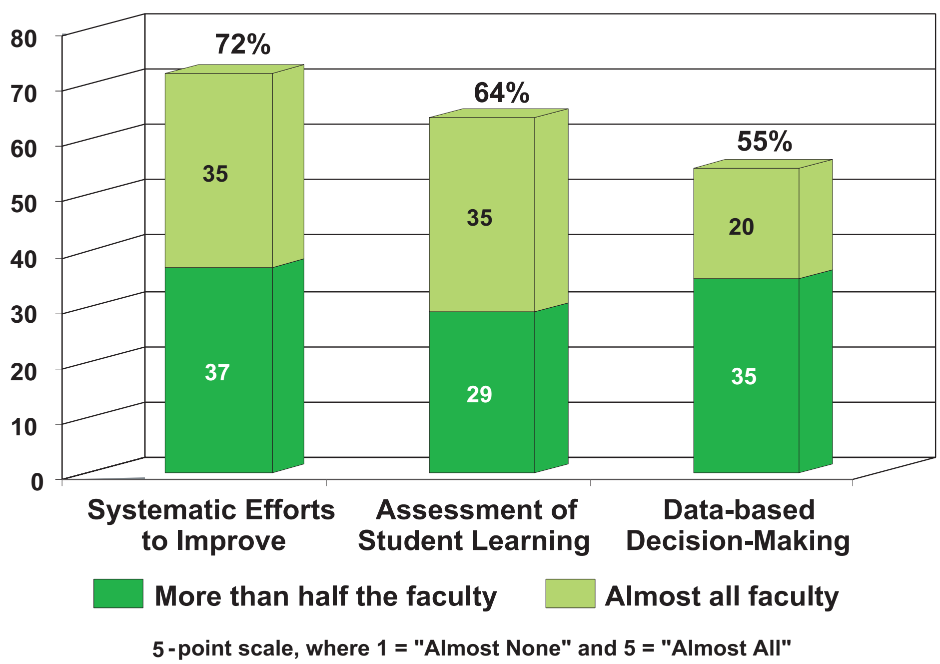
Figure 2. Faculty's Reports of Changes in Teaching Methods Since First Teaching the Course



Are these curricular and instructional changes attributable to EC2000 or to other influences shaping engineering education? Program chairs are much more likely than faculty to credit ABET (70% vs. 28%, respectively) and industry (78% vs. 28%) with having a moderate to strong influence on curricular changes in their programs. Faculty are more likely to take personal credit (82%) for changes they have made in their courses or to cite student feedback (54%) as having a moderate or great deal of influence. When other possible influences on curricular change at the course and program levels are controlled, however, faculty members believe ABET has had a statistically significant and independent influence on all measures of curricular or instructional change, and program chairs see a significant and independent ABET influence in two of three curricular areas. Industry feedback, however, is viewed as having a significant influence on only two of three course-level changes. Program chairs did not consider industry feedback as having a significant, independent influence on any changes at the program level.

EC2000 also requires that engineering programs assess student performance on the a-k learning outcomes and use the findings for program improvement. Program chairs report high levels of faculty support for these practices (see Figure 3). More than 75 percent of the chairs estimate that either more than half or almost all of their faculty supported continuous improvement efforts, and more than 60 percent report moderate to strong support for the assessment of student learning. Faculty corroborated this finding: Nearly 90 percent of the faculty respondents report some personal effort in assessment, and more than half report moderate to significant levels of personal effort in this area. For the most part, moreover, faculty members do not perceive their assessment efforts to be overly burdensome: Nearly 70 percent think their level of effort was "about right."

Figure 3. Program Chairs' Reports of Faculty Support for EC2000 Initiatives



Learning how to do assessment or incorporate active learning methods into courses may also influence faculty members' engagement in professional development opportunities focused on teaching and learning. This study finds that more than two-thirds of the faculty members report reading more about teaching in the past year, and about half engage in formal professional development activities, such as attending seminars or workshops on teaching, learning, and assessment, or participating in a project to improve engineering education. Depending on the activity, one-fifth to one-quarter of the faculty members say that in the past five years they have increased their teaching-and-learning-related professional development efforts.

One of the most important influences on faculty work in colleges and universities is the institutional reward system, which can encourage or discourage attention to teaching. The EC2000 accreditation criteria require that engineering programs be responsible for the quality of teaching, learning, and assessment, but do faculty members believe that their institutions value their contributions in these areas when making decisions about promotion, tenure, and merit-based salary increases? About half of the program chairs and faculty surveyed see no change in their institution's reward system over the past decade. About one third of the program chairs, however, report an increase over the past decade on the emphasis given to teaching in faculty hiring, promotion, tenure, and salary and merit decisions. In contrast, roughly one-quarter of the faculty respondents believed the emphasis on teaching in their reward systems had decreased in the same time period. Senior faculty members, however, tend to report increased emphasis on teaching in promotion and tenure decisions whereas untenured faculty are more likely to report decreased emphasis.

Differences in Student Experiences

Have the program changes reported by chairs and faculty had a measurable impact on the educational experiences of engineering undergraduates? The evidence suggests they have. Indeed, the experiences of the 2004 graduates differ in a number of ways from those of their counterparts of a decade earlier. The direction of seven of the 10 differences, moreover, is consistent with what one would expect if EC2000 were putting down roots. Compared to their 1994 counterparts, and after taking differences in graduates' and institutional characteristics into account, 2004 graduates reported:

- More active engagement in their own learning;
- More interaction with instructors;
- More instructor feedback on their work;
- More time spent studying abroad;
- More international travel;
- More involvement in engineering design competitions; and
- More emphasis in their programs on openness to diverse ideas and people.

Although they tend to be small, seven of 10 statistically significant differences between pre- and post-EC2000 graduates persist even after adjusting for an array of graduate and institutional characteristics.

The exceptions are the absence of differences in instructor teaching skills and the hours spent in cooperative or internship experiences, as well as the 2004 graduates' reports of a somewhat chillier diversity climate than that cited by their predecessors. The latter finding may be related to several factors: differences in the gender and racial/ethnic mix in 1994 and 2004, graduates' awareness of diversity issues, and/or their willingness to discuss and challenge prejudice or discrimination. The evidence provides no guidance in the way of an explanation.

Differences in Learning Outcomes

Assessments of graduates' skill levels on each of nine scales[1] reflecting EC2000 Criterion 3.a-k learning outcomes are based on graduates' self-reports of their ability levels at the time of graduation (using a five-point scale, where 1="no ability" and 5="high ability"). A growing body of research over the past 30 years has examined the adequacy of self-reported measures of learning and skill development as proxies for objective measures of the same traits or skills. When self-reports are aggregated to compare the performance of groups, they are generally considered to be valid measures of the skills under study. Although results vary depending on

[1] In statistical analyses, two of the 11 scales developed a priori to operationalize the a-k criteria collapsed into other scales, leaving a total of nine measurement scales to reflect student learning.

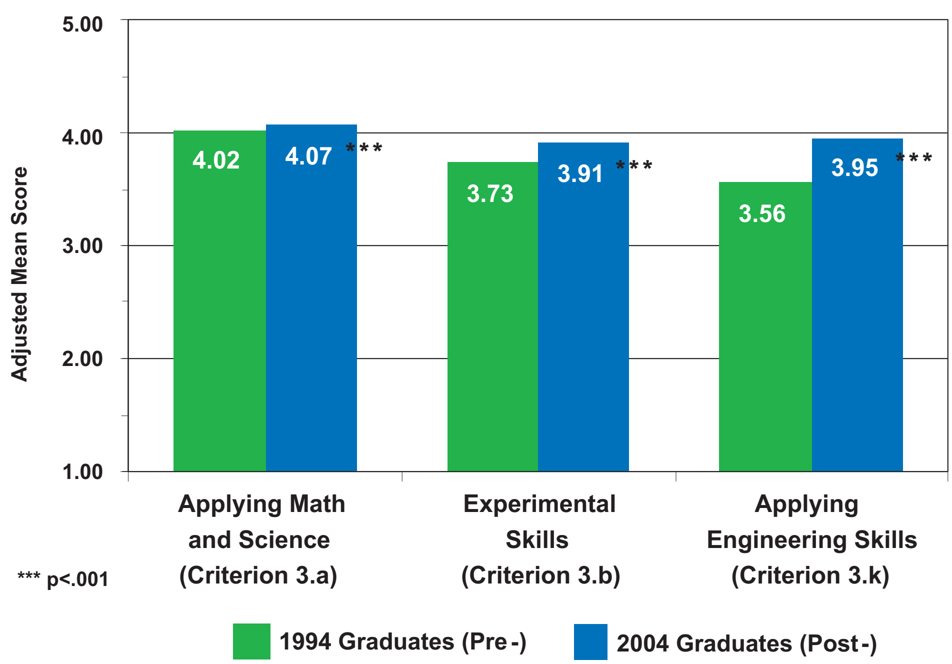
Key Findings: Differences in Learning Outcomes

- 2004 graduates better prepared than their 1994 counterparts.
- Professional skills gained; technical skills maintained.

the traits and instruments examined, these studies report correlations of .50 to .70, on average, between self-reports and such objective criterion measures as the ACT Comprehensive Test, the College Basic Academic Subjects Examination, and the Graduate Record Examination. The original research design called for comparison of graduates' scores on the 1996 and 2004 Fundamentals of Engineering examination as a measure of graduates' content mastery. However, the research team was unable to obtain permission to use those scores.

Figures 4 - 6 show the differences between 1994 and 2004 graduates' reports of their achievements on each of the nine scales reflecting the Criterion 3.a-k learning outcomes. In all cases, the differences are consistent with what one would expect under the assumption that EC2000 is having an impact on student learning. All differences, moreover, are statistically significant ($p < .001$), with effect sizes ranging from +.07 to +.80 of a standard deviation (mean = +.36).[2] Five of the nine effect sizes exceeded .3 of a standard deviation, an effect size that might be characterized as "moderate."

Figure 4. Differences in Graduates' Reports of Engineering Skills: Math, Science, and Engineering Skills Cluster



[2] An effect size is a standardized measure of the magnitude of the difference between two means after adjusting for differences in the variability of scores on the measure. The effect sizes reported here in standard deviation units can be expressed as estimated percentile-point differences between the groups. Assuming the mean for 1994 graduates' skill level on any outcome marks the 50th percentile, an average increase among 2004 graduates of .2 standard deviations is the equivalent of finding that the 2004s' skill level was at the 58th percentile, or an 8 percentile-point difference. Following are other, sample conversions: .4 SD = a 17 percentile-point difference; .6 = 23 percentile points; .8 = 29 percentile points, and 1.0 = a 34 percentile-point difference.

Figure 5. Differences in Graduates' Reports of Engineering Skills: Project Skills Cluster

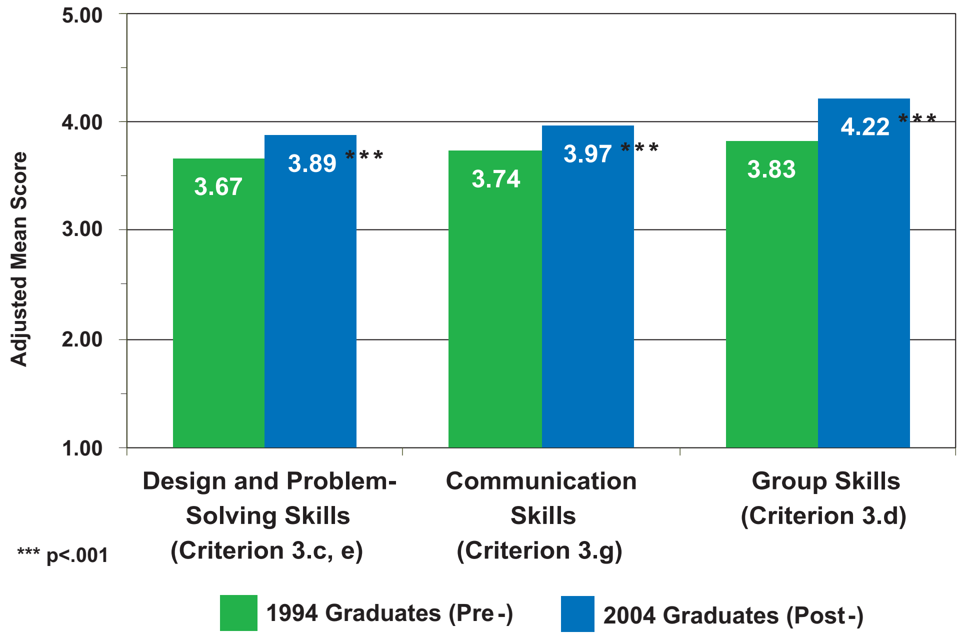
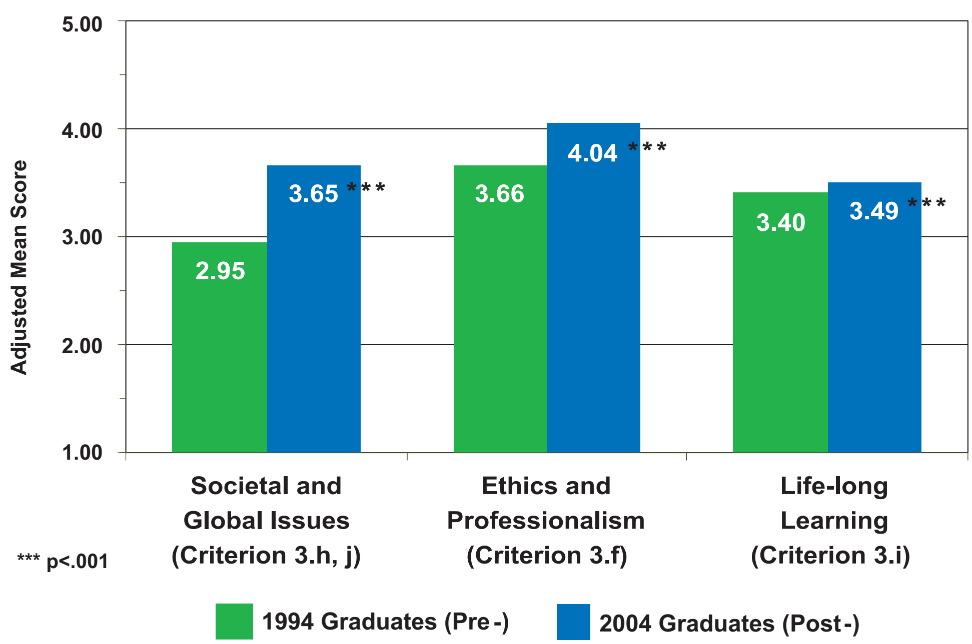


Figure 6. Differences in Graduates' Reports of Engineering Skills: Contexts and Professional Skills Cluster



The largest differences between 1994 and 2004 graduates are in five areas: Awareness of societal and global issues that can affect (or be affected by) engineering decisions (effect size = +.80 of a standard deviation), applying engineering skills (+.47 sd), group skills (+.47 sd), and awareness of issues relating to ethics and professionalism (+.46 sd). The smallest difference is in graduates' abilities to apply mathematics and sciences (+.07 sd). Despite that small but statistically significant difference, this finding is particularly noteworthy because some faculty members and others have expressed concern that developing the professional skills specified in EC2000 might require devoting less attention to teaching the science, math, and engineering science skills that are the foundations of engineering. This finding indicates not only that there has been no decline in graduates' knowledge and skills in these areas, but that more recent graduates report slightly better preparation than their counterparts a decade earlier. The evidence suggests that implementation of EC2000 is not only having a positive impact on engineering education, but, overall, that gains are being made at no expense to the teaching of basic science, math, and engineering science skills. [The study's final report provides information on pre-to-post-EC2000 differences by discipline.]

Evaluating Links between EC2000 and Learning Outcomes

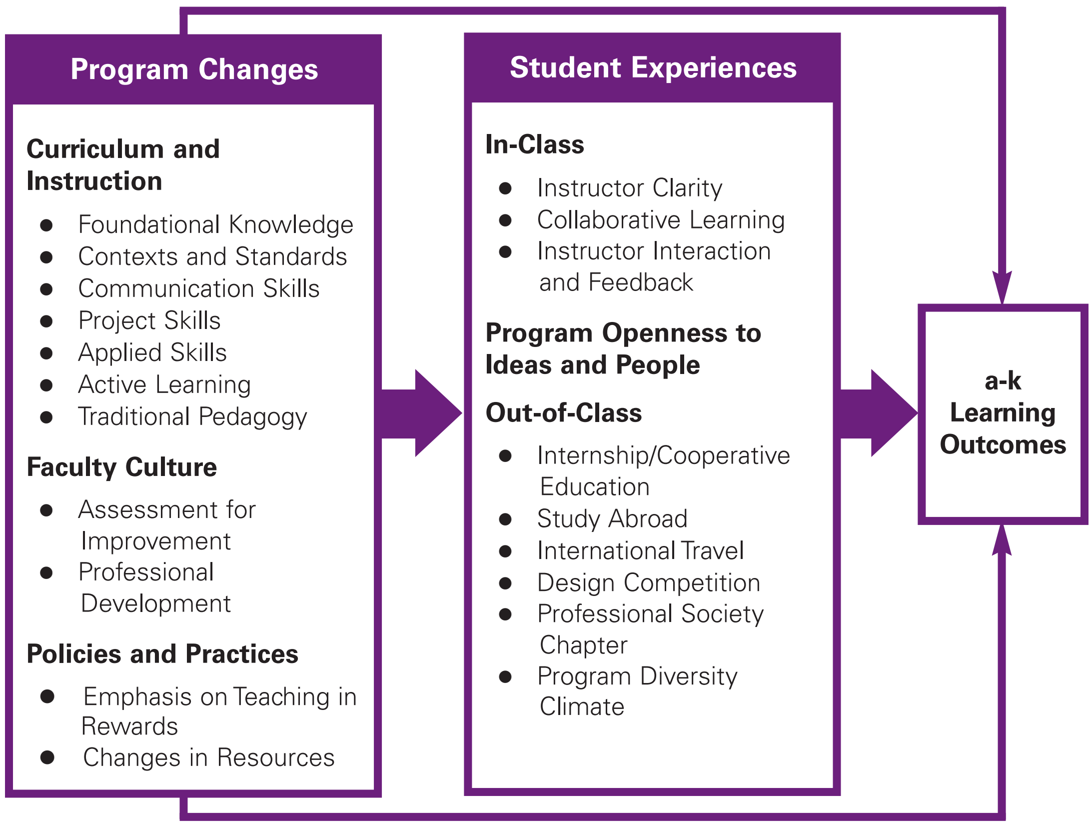
The central question of the EC2000 study was whether implementation of EC2000 is having any impact on the preparation of engineering graduates to enter their profession. The logic of the conceptual framework (see Figure 1) suggests a series of interconnected influences beginning with the effects of implementation of EC2000 on program changes and, subsequently, on students' experiences and, in turn, on graduates' learning.

Key Findings: Links Between EC2000 and Learning Outcomes

- Changes in programs and student experiences empirically linked to higher performance.

Following the logic of the conceptual model and based on multivariate statistical procedures, the findings provide moderate to strong evidence that EC2000-related changes in program curricula, policies, and practices, in faculty members' choices of pedagogies, and in the faculty culture more broadly are, indeed, reshaping students' engineering-related experiences (Figure 7 summarizes the analytical model used to evaluate linkages between EC2000 and student learning outcomes). The evidence of such influences remains, even when controlling for a battery of students' precollege traits and for the characteristics of the institutions they attended. Fourteen of 16 changes in program curricula, instruction, administrative practices or policies, or in the general faculty culture had statistically significant independent effects on at least one, and as many as five, student experiences. Ten of the 16 program or faculty changes had a significant influence on three or more student experiences. Pre- to post-EC2000 changes in emphasis on students' foundational knowledge and project skills, faculty reliance on traditional pedagogies (negative), and program emphasis on assessment for improvement are the most frequent influences shaping students' in- or out-of-class experiences. Although the source, direction, and strength of each influence vary somewhat with the student experience affected, a consistent pattern is apparent. The pre- to post-EC2000 changes in program curricula, practices and policies, and faculty activities and culture summarized above are positively related at statistically significant, if sometimes small-to-moderate, levels, even after taking other factors into account.

Figure 7. Analytical Model for Linking EC2000 to a-k Learning Outcomes



Finally, students' undergraduate program experiences, both in- and outside-the-classroom, are clearly linked to what and how much students learn. Nine of 10 measures of their in- and out-of-class experiences have statistically significant, positive, and sometimes substantial influences on graduates' reports of their ability levels on all nine of EC2000's a-k learning outcome measures. The clarity of the instruction received, the amount of interaction with and feedback from instructors, and exposure to active and collaborative learning experiences are consistently the most powerful influences on learning of any factors in the study, all having a positive influence on learning. Out-of-class experiences, however, also shape student learning. Important out-of-class experiences include internships or cooperative education experiences, participation in design competitions, and active participation in a student chapter of a professional society or association. These experiences significantly and positively affect learning in six or more of the nine skill areas measured. The magnitudes of these effects, however, were smaller than those of students' in-class experiences.

Employer Views

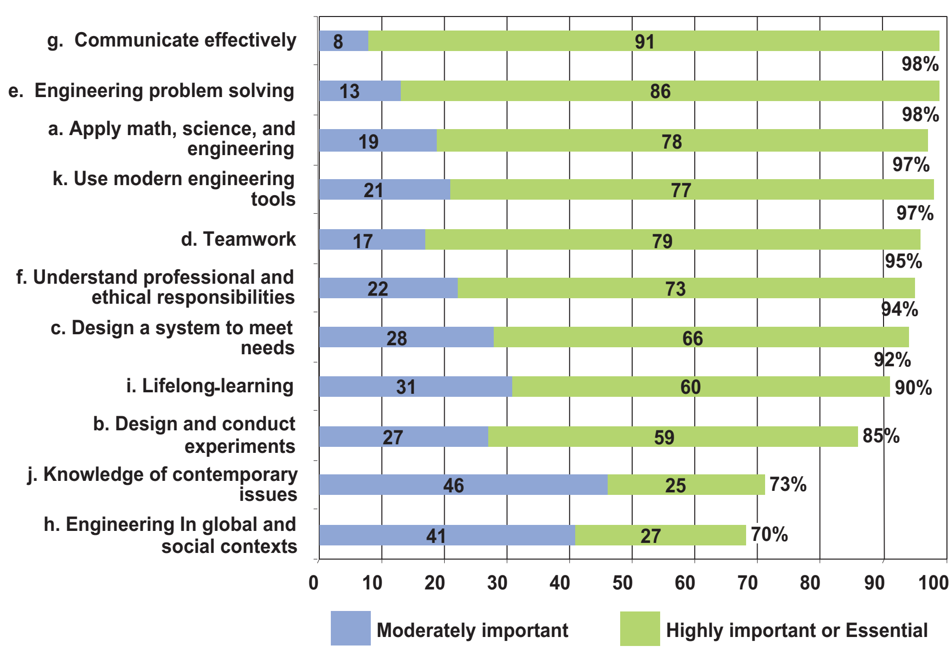
The 1,622 employer respondents in the EC2000 study are highly diverse in their geographic location, industry type, company size, educational attainment, and experience in evaluating engineers. Employers addressed three primary questions: How important is each of the 11 Criterion 3 competencies for today's new hires? How well prepared are your newly hired engineers (on each of five dimensions reflecting the 11 a-k criteria)? What changes have you observed over the past seven to 10 years in recent graduates' abilities (on each of the five dimensions)?

Figure 8 indicates that EC2000's a-k learning criteria are in substantial harmony with the views of employers on what new graduates should be able to do. For example, seven of 10 employers rate all 11 of the a-k criteria as at least moderately important, and at least six of 10 employers rate nine items as highly important or essential for new hires. Moreover, faculty members in the study indicate that they and their engineering programs are giving increased curricular emphasis to most of the areas that EC2000 emphasizes and that employers rate as most important – effective communication, teamwork, modern engineering tools, and design.

Key Findings: Employer Views

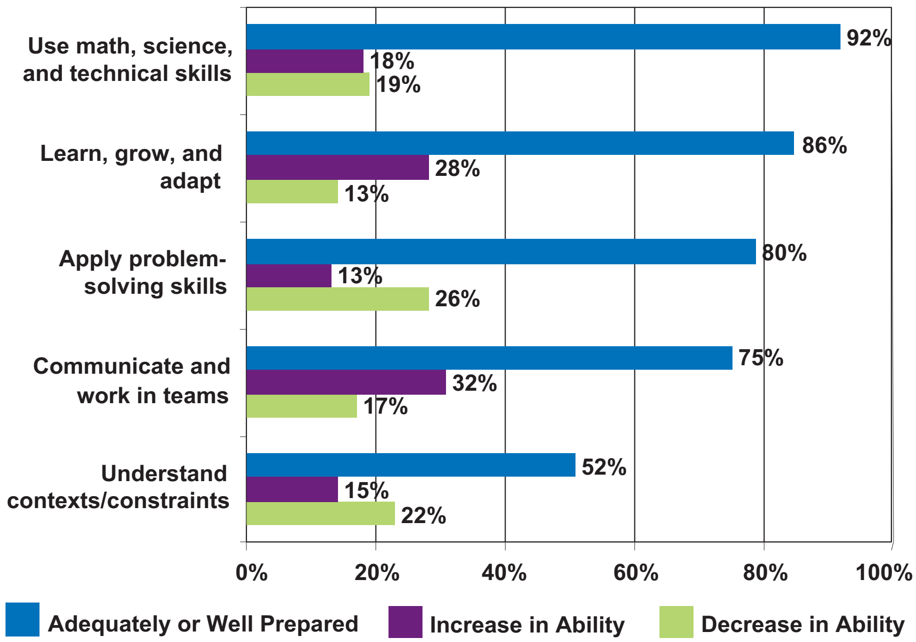
- National employers see more improvements than local firms.
- Employers say a-k outcomes still important.

Figure 8. Employers' Ratings of Importance of a-k Outcomes for New Hires



As shown in Figure 9, over 90 percent of the employers consider new engineering graduates to be adequately prepared or well prepared to use math, science, and technical skills, and about eight of 10 employers give recent graduates passing marks on their abilities to solve problems and to learn, grow, and adapt. Three of four employers assess graduates' teamwork and communication skills as at least adequate. Moreover, and since the introduction of EC2000, these employers report seeing modest increases in graduates' teamwork and communication skills, as well as in their abilities to learn, grow, and adapt to changing technologies and society. Math, science, and engineering skills appear unchanged over the past decade, but according to these employers, graduates' problem-solving skills appear to have

Figure 9. Employers' Reports of Engineer Preparation and Changes in Ability



declined modestly, although eight out of 10 employers judge the problem-solving skills of their new hires to be at least adequate. In contrast, barely half of the employers give an adequate rating to new graduates' understanding of the organizational, cultural, and environmental contexts and constraints of their work. Additionally, graduates' skills in this area, according to their employers, appear to have declined somewhat over the past decade.

Despite their heterogeneity, employers are in substantial agreement not only about the importance of a-k, but also about the preparation of new engineers, regardless of their engineering discipline. An extensive series of tests indicated only a handful of significant differences related to employers' engineering field, industry sector, degree attainment, or geographic location. Analyses indicate, however, that employers from larger companies that recruit nationally and hire the most engineers are more favorable in their judgments both of new engineers' preparation and of the pre-post-EC2000 change than are employers from smaller companies that recruit locally and hire fewer employees. This finding may suggest that the impact of EC2000 is just beginning to become visible to employers, and the larger national companies may be seeing the changes first.

Conclusions

The weight of the accumulated evidence collected for *Engineering Change* indicates clearly that the implementation of the EC2000 accreditation criteria has had a positive, and sometimes substantial, impact on engineering programs, student experiences, and student learning. Comparisons of 1994 and 2004 graduates' self-reported learning outcomes show 2004 graduates as measurably better prepared than their counterparts in all nine learning areas assessed. The greatest differences in student learning before and after EC2000 are in recent graduates' better understanding of societal and global issues, their ability to apply engineering skills, group skills, and understanding of ethics and professional issues.

Engineering Change assumed that if the new EC2000 accreditation criteria were having an impact, engineering programs would be moving to align their curricula and instructional methods with the goals of the new criteria, thus increasing student engagement in experiences that would promote the learning outcomes specified in the criteria. The findings from this study strongly suggest that improvements in student learning have indeed resulted from changes in engineering program curricula, teaching methods, faculty practices, and student experiences inside and outside the classroom. Although many dimensions of engineering programs shape learning, the findings of this study indicate that students' classroom experiences are the most powerful and consistent influences. Engineering programs and faculty can be confident that their efforts to improve engineering courses and programs will benefit students and the profession.

In the spirit of continuous improvement, ABET made a decision in 2002 to sponsor this study. The completion of the *Engineering Change* project establishes a baseline for the preparation of engineers and provides a model for future assessments of the state of undergraduate engineering education and student learning. As the first national study of an outcomes-based accreditation model, this research also informs ongoing discussions of accreditation policy among regional and professional accreditation agencies, state and federal legislators, and the general public – all of whom want evidence of the rigor of higher education quality assurance practices.

Appendix A: Study Design and Methods

Research Design and Data Collection

The *Engineering Change* study employed a cross-sectional, pre-/post-test design in which graduates of engineering programs who completed their degrees following the initiation of EC2000 were contrasted with graduates who had completed their programs before implementation of the new accreditation criteria. The study relied primarily on survey research methods. Information was collected from 40 colleges or schools of engineering offering more than 200 engineering programs in aerospace, chemical, civil, computer, electrical, industrial, and mechanical engineering. Survey information was collected from 1,243 faculty members, 147 program chairs, 5,494 graduates in the Class of 1994, 4,330 graduates of the Class of 2004, 39 deans, and 1,622 employers. Files maintained by the American Society for Engineering Education (ASEE), the U.S. Department of Education, and ABET provided information on institutional and program characteristics.

Sampling Design

The study population consisted of the 1,024 programs offering degrees in the seven target engineering disciplines accredited since 1990. The study relied on a disproportionate stratified random sample to ensure adequate sample sizes and program representativeness with respect to discipline, EC2000 review schedule, and participation in an NSF Engineering Education Coalition during the 1990s. Adjustments were also made to include engineering colleges serving historically underrepresented populations. Table 2 lists the participating institutions.

Table 2. Participating Institutions

Doctoral Institutions
Arizona State University
Case Western Reserve University
Clemson University
Cornell University
Georgia Institute of Technology
Howard University
Illinois Institute of Technology
Iowa State University
Lehigh University
Marquette University
Massachusetts Institute of Technology
Ohio State University
Princeton University
Purdue University
Syracuse University
Temple University
Texas A&M University
University of Arkansas
University of California, Los Angeles
University of Florida
University of Illinois at Chicago
University of Michigan
University of Missouri-Columbia
University of Notre Dame
University of the Pacific
University of Texas at Arlington
University of Texas at Austin
Virginia Polytechnic Institute and State University
Western Michigan University
Worcester Polytechnic Institute

Master's Institutions
California State Polytechnic University, Pomona
California State University, Sacramento
Embry-Riddle Aeronautical University
North Carolina A&T State University
Tuskegee University
Youngstown State University

Bachelor's and Specialized Institutions
South Dakota School of Mines and Technology
Tri-State University
Union College
United States Military Academy

Sources of Evidence

Figure 10 summarizes the study's sources of evidence. Check marks indicate which sources contributed data relevant to each component of the study's guiding conceptual model (see Figure 1). Program information was obtained from ABET, the American Society for Engineering Education, and the U.S. Department of Education's Integrated Postsecondary Education Data System. All other information came from mailed and on-line surveys of program graduates (1994 and 2004), program chairs, faculty members, and employers. Deans were interviewed by telephone. All data were gathered during the 2003-2004 academic year. Although the original research design also called for analysis of graduates' scores on the 1996 and 2004 Fundamentals of Engineering examination as measures of graduates' content mastery, the research team was unable to obtain permission to use those scores.

Figure 10. Sources of Evidence for *Engineering Change*

EC2000 Impact Areas	Data Sources						
	ASEE, ABET, and IPEDS Databases	**2004 Graduates**	**1994 Graduates**	**Deans**	**Program Chairs**	**Faculty**	**Employers**
Institutional and Program Information	✓			✓	✓	✓	
Curriculum and Instruction		✓	✓		✓	✓	
Faculty Culture				✓	✓	✓	
Administrative Policy and Organizational Influence				✓	✓	✓	
Student Outcomes and Educational Experiences		✓	✓		✓	✓	✓
	7 institutional and program characteristics	100 survey items	92 survey items	Interviews	100 survey items	85 survey items	36 survey items

Sample Representativeness

Prior to all analysis, sample respondents were weighted to produce a sample representative of the parent population. Program chairs' responses were adjusted to correct for any response bias by Carnegie Classification and participation in the National Science Foundation's (NSF) Engineering Education Coalition Program during the 1990s. Faculty data were weighted to correct for any response bias related to respondents' sex, discipline, and institutional NSF Coalition participation. Data from the 1994 and 2004 graduates were adjusted to be representative by sex and discipline. Adjustments were also made to correct for differences in institutional response rates within each sampled group (excepting program chairs).

Data Analysis

The primary analytical procedures included principal components factor analysis, item and scale analysis, analysis of covariance, and hierarchical, ordinary least-squares multiple regression. In all inferential statistical tests, differences in graduates' pre-college characteristics and in the traits of the institutions they attended were controlled.

Appendix B: *Engineering Change* Study Team

Center for the Study of Higher Education, The Pennsylvania State University

- Dr. Lisa R. Lattuca, Project Director and Co-Principal Investigator
- Dr. Patrick T. Terenzini, Co-Principal Investigator
- Dr. J. Fredericks Volkwein, Co-Principal Investigator
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- Graduate Research Assistants: Vicki L. Baker, Robert J. Domingo, Betty J. Harper, Amber D. Lambert, Javzan Sukhbaatar
- Suzanne S. Bienert, Staff Assistant

The Pennsylvania State University's Center for the Study of Higher Education (CSHE) is one of the nation's first research centers established specifically to study postsecondary education issues. For over 30 years, research teams composed of nationally recognized faculty, highly qualified graduate students, and experienced professional staff have examined critical issues that influence the policies and practices of postsecondary institutions. To that end, CSHE is dedicated to conducting and disseminating theory-based empirical research designed to improve higher education practice and policy; providing high-quality data and analysis to institutional, state, and federal policy-makers; and supporting graduate training for students in the Higher Education Program at Penn State.

Persons with questions or wishing additional information are invited to contact Dr. Lisa R. Lattuca, Project Director (lattuca@psu.edu).

Appendix C: *Engineering Change* National Advisory Board

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Director, Center for the Advancement of Scholarship on Engineering Education
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American Society of Mechanical Engineers International

Dr. David N. Wormley
Dean of the College of Engineering and Professor of Mechanical Engineering
The Pennsylvania State University

*Member, 2004-2006
**Member, 2002-2004

Appendix D: *Engineering Criteria 2000*

The following is an excerpt from the *Criteria for Accrediting Engineering Programs* that were effective during the 2001-2002 ABET accreditation cycle.

Engineering Change focused on Criterion 3.a-k.

I. GENERAL CRITERIA FOR BASIC LEVEL PROGRAMS

It is the responsibility of the institution seeking accreditation of an engineering program to demonstrate clearly that the program meets the following criteria.

Criterion 1. Students

The quality and performance of the students and graduates are important considerations in the evaluation of an engineering program. The institution must evaluate, advise, and monitor students to determine its success in meeting program objectives.

The institution must have and enforce policies for the acceptance of transfer students and for the validation of courses taken for credit elsewhere. The institution must also have and enforce procedures to assure that all students meet all program requirements.

Criterion 2. Program Educational Objectives

Each engineering program for which an institution seeks accreditation or reaccreditation must have in place:

(a) detailed published educational objectives that are consistent with the mission of the institution and these criteria
(b) a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated
(c) a curriculum and processes that ensure the achievement of these objectives
(d) a system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program.

Criterion 3. Program Outcomes and Assessment

Engineering programs must demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Each program must have an assessment process with documented results. Evidence must be given that the results are applied to the further development and improvement of the program. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the program, including those listed above, are being measured. Evidence that may be used includes, but is not limited to the following: student portfolios, including design projects; nationally-normed subject content examinations; alumni surveys that document professional accomplishments and career development activities; employer surveys; and placement data of graduates.

Criterion 4. Professional Component

The professional component requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The engineering faculty must assure that the program curriculum devotes adequate attention and time to each component, consistent with the objectives of the program and institution. Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political. The professional component must include:

(a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline
(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study
(c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

Criterion 5. Faculty

The faculty is the heart of any educational program. The faculty must be of sufficient number; and must have the competencies to cover all of the curricular areas of the program. There must be sufficient faculty to accommodate adequate levels of student-faculty interaction, student advising and counseling, university service activities, professional development, and interactions with industrial and professional practitioners, as well as employers of students.

The faculty must have sufficient qualifications and must ensure the proper guidance of the program and its evaluation and development. The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, engineering experience, teaching experience, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and registration as Professional Engineers.

Criterion 6. Facilities

Classrooms, laboratories, and associated equipment must be adequate to accomplish the program objectives and provide an atmosphere conducive to learning. Appropriate facilities must be available to foster faculty-student interaction and to create a climate that encourages professional development and professional activities. Programs must provide opportunities for students to learn the use of modern engineering tools. Computing and information infrastructures must be in place to support the scholarly activities of the students and faculty and the educational objectives of the institution.

Criterion 7. Institutional Support and Financial Resources

Institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the engineering program. Resources must be sufficient to attract, retain, and provide for the continued professional development of a well-qualified faculty. Resources also must be sufficient to acquire, maintain, and operate facilities and equipment appropriate for the engineering program. In addition, support personnel and institutional services must be adequate to meet program needs.

Criterion 8. Program Criteria

Each program must satisfy applicable Program Criteria (if any). Program Criteria provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline. Requirements stipulated in the Program Criteria are limited to the areas of curricular topics and faculty qualifications. If a program, by virtue of its title, becomes subject to two or more sets of Program Criteria, then that program must satisfy each set of Program Criteria; however, overlapping requirements need to be satisfied only once.

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