AC 2010-1335: LIBERAL EDUCATION FOR THE ENGINEER OF 2020: ARE ADMINISTRATORS ON BOARD?

Betty Harper, Pennsylvania State University

Lisa Lattuca, Pennsylvania State University

Alexander Yin, Penn State University

Patrick Terenzini, Pennsylvania State University

Liberal Education for the Engineer of 2020: Are Administrators On-Board?

Abstract

Engineering educators are being pressed to prepare students for the challenges of a dynamic, global workplace and society. The National Academy's reports, *The Engineer of 2020: Visions of Engineering in the New Century*[1] and *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*[2], provide guidance to the engineering education community as it seeks to meet these challenges. *The Engineer of 2020*, in particular, identifies the attributes and skills that engineers will need if the U.S. is to maintain its economic and engineering leadership in a rapidly changing technological and globalized environment. The report portrays engineering education of the future as a liberal education, stressing interdisciplinarity, communication, leadership, and understanding the multiple, interconnected contexts in which engineering exists. This paper presents data from one component of a larger, national study that examines the extent to which undergraduate engineering programs are on-board with the NAE's vision and are providing educational experiences consistent with the report's goals.

Data come from a survey of engineering administrators and focus in particular on their responses to questions about the role of liberal education in the preparation of engineers. The study's institutional sample was drawn from the population of four-year engineering schools offering two or more of the following ABET-accredited undergraduate engineering programs: biomedical/bio-engineering, chemical, civil, electrical, industrial, or mechanical. A 6x3x2 disproportionate stratified random sample was drawn using the following strata: six discipline levels, three levels of highest degree offered (bachelor's, master's, or doctorate), and two levels of type of control (public or private). The sample includes 32 U.S. colleges/schools of engineering. Thirty associate deans (94%) and 84 program chairs (67%) responded.

Analyses indicate the majority of respondents are familiar with the goals of *The Engineer of 2020*. Administrators tended to agree with statements such as "humanities and social science courses are very important in preparing engineers" and that the undergraduate engineering curriculum should "prepare students to assume community leadership roles." Although there were some small differences, analyses, generally did not support the hypotheses that respondents' levels of agreement with the NAE's vision would vary with institutional mission (bachelor's, master's or doctoral) and/or size. Similarly, administrators' views on liberal learning were not linked to the amount of their industry experience.

Introduction

In recent years, external and internal forces have pushed engineering educators to reshape their programs' curricula to prepare students more effectively to meet the challenges of a dynamic, global workplace and society. Numerous reports describing this need have emerged from such bodies as the National Academy of Engineering, the National Science Foundation, and other federal agencies; engineering industry organizations; and professional societies. While the focus of each report varies, they have certain themes in common. All argue that to meet the needs of the future and to maintain America's economic and technological dominance on the world stage, engineers need to develop a set of professional skills that complement their technical knowledge. The National Academy of Engineering's reports, *The Engineer of 2020: Visions of Engineering in the New Century*[1] and *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*[2] (collectively referred to throughout this paper as the "E2020 reports") focus specifically on the knowledge, skills, and dispositions that should be emphasized in undergraduate engineering programs and how those skills might be incorporated into undergraduate education. For example, the NAE states that engineers need to be prepared to work collaboratively in culturally diverse and global settings. In order to remain relevant in an evolving field, they must also be creative and innovative, imbued with an entrepreneurial spirit, and educated for leadership and life-long learning. Traditionally, the development of attributes such as these have not been the primary goals of the undergraduate engineering curriculum, although recent changes in accreditation standards strongly encourage engineering programs to help students develop teamwork and lifelong learning skills.

While support for what have been understood historically as liberal (or general) education goals fuels many discussions in engineering education community, the level to which these goals currently permeate engineering programs is unclear. This paper focuses on what we view as the "liberal education" aspects of NAE's vision for the engineer of 2020 and the level of support for this vision among administrators (associate deans for undergraduate education and program chairs) from a diverse and nationally representative sample of engineering programs.

Engineering for the 21st Century

For the past two decades, government, business, and professional bodies have urged the engineering education community to reform undergraduate curricula and programs to better prepare students for the emerging challenges of the engineering workplace. In 1994, the Engineering Deans Council and Corporate Roundtable of the American Society for Engineering Education released *Engineering Education for a Changing World*, commonly referred to as the Green Report.[3] The Green Report argued that "with the end of the Cold War, engineering education needed a new set of guiding principles to replace those that had been developed following World War II. Rather than a world based largely on superpower competition and national security, engineers now faced a world of intense international economic competition and widespread public uncertainty about the uses of technology" (Preface, paragraph 1) The report called for an increased focus on skills and activities such as teamwork, communication, appreciation for diversity, multidisciplinarity, and understanding of societal contexts and largely foreshadowed the changes to ABET's (Accreditation Board for Engineering and Technology) accreditation criteria unveiled in 1997.[4]

As other nations' educational standards rise and economies grow, the concerns first expressed in the Green Report have grown. The engineering education community is not alone in its view that engineering has a critical role to play in America's economy and future. The National Academy of Science and the Institute of Medicine joined NAE in a 2007 report, entitled *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,*[5] which warned that "the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength" (p. 3).

In addition to the E2020 reports, other books have attempted to address these concerns, including *The 21st Century Engineer: A Proposal for Engineering Education Reform,*[6] *Educating Engineers: Designing the Future of the Field,*[7] and *Engineering for a Changing World: A Roadmap to the Future of Engineering Practice, Research, and Education*.[8] The authors of each of these volumes, like the E2020 reports, have called for more engagement with real-world projects, questioned the level of specialization needed in undergraduate education, and advocated for greater attention to the liberal arts and humanities in engineering education.

After reviewing the findings and recommendations of the numerous reports concerning the future of engineering education, James Duderstadt, President Emeritus and University Professor of Science and Engineering at the University of Michigan, concluded that "the key to producing such world-class engineers is to take advantage of the fact that the comprehensive nature of American universities provide the opportunity for significantly broadening the educational experience of engineering students, provided that engineering schools, accreditation agencies such as ABET, the profession, and the marketplace are willing to embrace such an objective."[8] Duderstadt argues that this should be achieved by requiring engineers to complete a bachelor's degree in a traditional liberal arts discipline (such as biology, philosophy, economics) before continuing their professional education through graduate study in engineering. This educational model would be similar to that followed by those preparing for careers in law, medicine, and business. In contrast, ABET's EC2000 accreditation criteria allow a more moderate approach that places greater emphasis on liberal education in the undergraduate engineering program. NAE's E2020 reports occupy a middle ground, advocating for even greater curricular breadth and liberal education than ABET's EC2000 accreditation criteria require but stopping short of a complete restructuring of undergraduate engineering education. *The Engineer of 2020*, in particular, presents the engineering education of the future as liberal education, stressing the roles of interdisciplinarity, communication, leadership, and contextual understanding in engineering problem-solving and practice.

Liberal and Professional Education in Historical Perspective

For most of the history of U.S. higher education, the goals of liberal education were thought to be different from – and by some, incompatible with – the goals of professional education in fields such as engineering, business, education, law, and medicine. The roots of these views are both historical and philosophical, but the separation of liberal education (often called general education) from the academic major (the vocationally oriented component of the curriculum) is a relatively recent phenomenon. More recent are the calls for greater integration of the two components of a collegiate education.

From the early 1600s, when the first colonial college was founded in what would become the United States, through the 1800s, the collegiate curriculum was highly prescribed. The American colonial college of the 1600s and 1700s sought to prepare men for civic life by emphasizing the practical and moral aims of learning and the unity of knowledge;[9] students studied philosophy, classical languages (Greek, Latin, and Hebrew), mathematics, physics, and theology with the goals of developing the skills of logic and communication. New subject areas, such as history, politics, and commerce, were added only gradually as the values of the Enlightenment took hold and the science and social science disciplines emerged. By the early

1800s, critics of higher education advocated the incorporation of scientific and technical fields such as engineering in the college curriculum. During this period, some U.S. colleges added courses in science (beyond the study of "natural philosophy" as physics was then known), music, teacher education, architecture, modern languages, business, and engineering. By mid-century, the curriculum had expanded considerably and institutions such as the University of New Hampshire and Harvard had adopted elective systems that allowed students greater curricular choices.[10]

Still, it was not until the mid-1800s that scientific and technical courses were widely accepted and adopted. These changes in the collegiate curriculum resulted from a confluence of events, including the expansion of secondary education in the U.S. and the concomitant rise in the age of matriculating students, which allowed a clearer distinction between higher education and what preceded it. The mid- and late-nineteenth century witnessed an emerging emphasis on academic specialization and the advancement of knowledge (as opposed to only its transmission). The birth of the American university was encouraged by the adoption of elements of the German research university model and the continued expansion of the nation's economy and industrial base, both of which required an educated populace.[11,12]

By 1900, the highly prescribed classical curriculum had been supplanted in most U.S. colleges and universities by a curricular model that combined study in an academic major (a specialization) with courses to fulfill "general education" requirements. Conrad and Wyer[13] noted:

> Liberal education, regarded as the ideal of higher education in the eighteenth century and as a major institutional form of higher education in the nineteenth century, had become regarded, by the turn of the [20th] century, in an even more limited sense as one component, sometimes a minor component, of the undergraduate curriculum (p. 15).

Rothblatt[12] reported that a variety of programs of general and specialized education were in place in the latter half of the 1800s. The principle of "breadth" was achieved through electives and compulsory first- and second-year courses, while depth was provided through more specialized courses. Some institutions instituted majors and minors to permit specialization while others experimented with new degree programs. These reforms are evident in today's college and university curriculum, which combines study in a major, the venue for career-oriented education, with general education courses that, at least in theory, provide students with the knowledge and skills needed to lead fulfilling and productive lives, but also to be better and more adaptive and "life-long" learners.

From its inception, this new educational model attracted criticism. By the early 1900s, general education reform movements sought better ways to provide students with both breadth of study and a coherent curriculum. Educators debated the role of general education and its proper content, as well as the goals of academic specialization.[14, 15] By 1945, a blue-ribbon committee of the Harvard faculty issued a report calling for a balance between general and specialized education. Known as the "Harvard Redbook,"[16] the report defined general education not as "some airy education in knowledge in general" but as "that part of a student's whole education which looks first of all to his life as a responsible human being and citizen" (p. 51). The complement to general education was specialization, what we think of today as the major field, which was presumed to round students' educations by preparing them for the pursuit of an occupation. Echoing the ideas of educational philosopher John Dewey, the Redbook explicitly addressed the relationship between the goals of general education and preparation for a vocation through specialized study, arguing: "These two sides of life are not entirely separable, and it would be false to imagine education for the one as quite distinct from education for the other…" (pp. 51-52).

Today, concerns about the quality of general education and the academic major continue. The Association for American Colleges and Universities has issued numerous reports calling for greater attention to "liberal learning" defined as development of the knowledge and skills needed for work and citizenship in a globalized society (e.g., AACU[17]). Educators are also increasingly calling on colleges and universities to integrate students' learning across general education and the major, recognizing that the goals of liberal and professional education are not only similar, but often overlapping.[18,19] These complementary goals include, among others, communication competence, critical thinking, contextual competence, ethics, leadership capacity, and motivation for continued learning.[18]

Today's calls to improve both the major and general education focus on the need to prepare students for lives as members of communities in a diverse, global, technologically and socially dynamic world. In engineering education, the press for educational innovation is particularly acute, emanating from the National Science Board, the National Academy of Engineering, ABET, and the American Society for Engineering Education, which recently published a report entitled, *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education*.[20] Addressing these concerns about the capacity of engineering education to prepare the engineers of the future requires that engineering faculty members and academic administrators recognize the importance of liberal learning in engineering education and incorporate in their curricula.

Goals of the Study

This paper presents findings based on analyses of two surveys conducted as part of a national study, *Prototype to Production: Conditions and Processes for Educating the Engineer of 2020* (P2P).[21] Among other things, the P2P study examined the extent to which administrators overseeing undergraduate engineering programs share NAE's view of the attributes needed by "the engineer of 2020" and whether the educational experiences their programs provide are consistent with goals specified in the Academy's report. Although NAE's E2020 reports reinforce the development of the core technical knowledge and skills (e.g., strong analytical and problem solving skills) considered essential for engineers, the reports also recommend that engineering programs help students develop their ethical sensibilities, leadership, and intercultural communication skills. The reports also stress the need to appreciate and understand non-engineering disciplines and the contributions of interdisciplinary collaborations and knowledge to engineering practice. Specifically, the paper addresses the following questions:

1) How familiar are engineering administrators (associate deans for undergraduate education and program chairs) with NAE's vision and recommendations, as expressed in *The Engineer of 2020* (2004)[1], *Educating the Engineer of 2020* (2005)[2], and *Rising Above the Gathering Storm* (2007)[6]?

2) To what extent do engineering administrators agree with the views expressed in the E2020 reports regarding the importance of curricular breadth and the value of liberal education for engineering?

3) Do administrators' views vary by administrative function (associate dean or chair), engineering discipline, institutional mission (relative emphasis on teaching and research), or institutional size?

Methods

Survey development

During the spring 2009 academic term, 32 associate deans of undergraduate education (or their equivalents) and 126 engineering program chairs from seven engineering fields (biomedical/bio-engineering, chemical, civil, electrical, general, industrial, and mechanical) were invited to participate in a survey that asked them to report on the nature of their undergraduate engineering program policies, practices, curricula and instruction; professional development requirements and opportunities for faculty; reward systems; and views of engineering and engineering education. Survey instrument development entailed a rigorous, two-year process that included literature reviews on key survey topics using the ASEE database, Compendex, and various higher education databases; individual interviews with administrators, faculty, and alumni at Penn State University and City College of New York; and focus-group interviews with students at those same institutions. The process produced two instruments, one for associate deans and another for program chairs. The process also entailed focus group interviews with and reviews by Penn State engineering administrators and faculty to ensure the content validity and that items and response options were appropriate and understandable.[22]

Population, Sample, and Data Collection

The study's sampling plan was designed to provide a nationally representative set of engineering programs. The institutional population was defined as all four-year engineering schools offering two or more ABET-accredited programs in the "big five" engineering disciplines: chemical, civil, electrical, industrial, and mechanical. Based on the recommendation of the overall project's National Advisory Board, biomedical/ bio-engineering was included as one of the focal disciplines, despite its relatively small size, due to its prominence in *Educating the Engineer of 2020* and its position as a growing discipline. Because information from the P2P studies were to inform analyses of a closely related set of case studies, the sample was also refined to include three institutions offering general engineering programs. Together, these programs (plus general engineering) accounted for 70 percent of all baccalaureate engineering degrees awarded in 2007.

The sampling frame was drawn from the American Society for Engineering Education's database using institution and program-level information for the 2007-08 academic year for currently enrolled students and faculty.

A 6x3x2 disproportionate stratified random sample was drawn using the following strata: six discipline levels, three levels of highest degree offered (bachelor's, master's, or doctorate), and two levels of "type of control" (public or private). The total sample of 32 four-year colleges and universities was “pre-seeded” with nine pre-selected institutions. These included six case study institutions that were participants in a companion project *(Prototyping the Engineer of 2020: A 360-degree Study of Effective Engineering Education*[23]) and three institutions with general engineering programs. Since one of the six case study institutions offers only a general engineering degree, three institutions with general engineering programs were purposely selected for the sample. Penn State’s Survey Research Center selected 23 additional institutions at random from the population within the 6x3x2 framework above, including two HBCUs and three HSIs. The sampling design ensured that the sample institutions (see Table 1) are representative of the population with respect to type, mission, and highest degree offered. Chi-square goodness-of-fit tests also indicated that the undergraduate engineering students at these institutions were representative of the overall population with respect to discipline, race/ethnicity, gender, class status, and full-/part-time enrollment status.

Table 1: P2P Institutional Sample

Research Institutions:	Master’s/Special Institutions:
Arizona State University (Main & Polytechnic)[1]	California Polytechnic State University[3]
Brigham Young University	California State University, Long Beach
Case Western Reserve University	Manhattan College
Colorado School of Mines	Mercer University
Dartmouth College	Rose-Hulman Institute of Technology
Howard University[1, 2]	University of South Alabama
Johns Hopkins University	
Massachusetts Institute of Technology[1]	
Morgan State University[2]	**Baccalaureate Institutions:**
New Jersey Institute of Technology	Harvey Mudd College[1]
North Carolina A&T[2]	Lafayette College
Purdue University	Milwaukee School of Engineering
Stony Brook University	Ohio Northern University
University of Illinois at Urbana-Champaign	Penn State Erie, The Behrend College
University of Michigan[1]	West Virginia University Institute of Technology
University of New Mexico[3]	
University of Texas, El Paso[3]	
University of Toledo	
Virginia Polytechnic Institute and State University[1]	

[1] P360 Institution
[2] Historically Black College or University
[3] Hispanic-Serving Institution

Penn State’s Survey Research Center handled data collection from program chairs using a web-based questionnaire and following procedures largely the same as those recommended by Dillman.[24] Project staff members completed data collection from associate deans for undergraduate education using a mailed survey and procedures similar to those recommended by Dillman.

Thirty associate deans (94%) and 84 program chairs (67%; 5 biomedical/bio-engineering, 12 chemical engineering, 19 civil engineering, 17 electrical engineering, 2 general engineering, 10 industrial engineering, and 19 mechanical engineering) responded to the survey. The Chi-square goodness-of-fit test indicated that the program chairs were representative of the population with respect to ABET accredited engineering programs when examining just the "big five" disciplines and biomedical/bio-engineering.

Variables

The independent variables included: administrator position (associate dean or program chair), respondents' institution size based on the 2005 Size and Setting Carnegie Classification[25] (i.e., small, medium, and large), respondents' institution type, which was based on the Basic Carnegie Classification (bachelor's, master's, or doctorate), and respondents' industry experience (measured by time in years) and engineering discipline.

The dependent variables were administrators' familiarity with three national reports cited above (*The Engineer of 2020, Educating the Engineer of 2020*, and *Rising above the Gathering Storm*). Administrators' self-reported their awareness of the report on a five-point scale (1 = Unaware of it, 2= Heard of it, 3= Read/ heard summaries, 4= Read parts, 5= Read most of it). Associate deans and program chairs also reported attitudes toward statements about importance of curricular breadth and the value of liberal education in undergraduate engineering (see Table 2).

Table 2: Dependent Variable Questions.

Several recent reports discuss the changing knowledge and skills engineers will need in the future and how engineering education needs to change. Do you agree or disagree with the following statements about undergraduate engineering education?

a. Humanities and social science courses are very important in preparing engineers.
b. Interdisciplinary learning – inside and outside engineering –should be part of the engineering curriculum.

Do you agree or disagree that the undergraduate engineering curriculum should:

a. Teach students about intercultural communication.
b. Teach students to consider all relevant factors (e.g., social, cultural, environmental) in designing solutions.
c. Prepare students to assume community leadership roles.
d. Address ethical issues in multiple courses.
e. Provide opportunities for students to prepare for occupations other than engineering (e.g., business, medicine, law).

Scale: 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5=strongly agree

Analytical Procedures

A correlation matrix was used to examine the relationships between administrators' industry experience and their familiarity with the NAE reports and their attitudes towards statements relating liberal learning and engineering education extent (Table 2). Differences between program chairs' and associate deans' responses were tested using one-way analysis of variance (ANOVA). ANOVAs assessed, also, the extent to which institutional size and type influence engineering administrators' attitudes. Where significant groups differences were found regarding agreement levels on the liberal education components and the NAE reports, Boneferroni post-hoc comparisons were conducted to determine which groups differed at statistically levels.

Findings

Overall, the findings suggest that most administrators surveyed support the NAE report's goals and that most are familiar with the reports articulating these goals. This support and familiarity varies little despite variations in administrators' industry experience and the size and mission of their institutions.

Familiarity with NAE Reports

Perhaps not surprisingly, most of the associate deans surveyed reported some familiarity with and exposure to the NAE reports (Table 3). The majority of the program chairs were also familiar with *The Engineer of 2020* and *Educating the Engineer of 2020*. The chairs, however, reported less familiarity than the associate deans with *Rising above the Gathering Storm*, a more broad-based report published collectively by the NAE, the National Academy of Sciences, and the Institute of Medicine. Ninety percent of the associate deans and 70 percent of the program chairs had at least read or heard summaries of the first of the NAE reports, *The Engineer of 2020*, while 90 percent of the associate deans and 64 percent of the program chairs reported reading or hearing summaries of *Educating the Engineer of 2020*. While 87 percent of the associate deans were familiar with *Rising above the Gathering Storm*, only 52 percent of program chairs had at least read or heard summaries of this report. The differences between associate deans and program chairs in their familiarity with all three reports were statistically significant ($p = .006$, $p = .017$, and $p = .000$, respectively). On average, associate deans were more familiar with *The Engineer of 2020*, *Educating the Engineer of 2020*, and *Rising above the Gathering Storm* than were program chairs.

Table 3: Familiarity with National Academy of Engineering Reports.

	The Engineer of 2020		***Educating the Engineer of 2020***		***Rising Above the Gathering Storm***	
	Associate Deans (n=30)	Program Chairs (n=82)	Associate Deans (n=30)	Program Chairs (n=82)	Associate Deans (n=30)	Program Chairs (n=81)
Unaware of it	3.3%	11.0%	6.7%	15.9%	0.0%	27.2%
Heard of it	6.7	19.5	3.3	20.7	13.3	21.0
Read/heard summaries	16.7	14.6	30.0	15.9	23.3	12.3
Read parts	23.3	34.1	23.3	30.5	33.3	29.6
Read most or all	50.0	20.7	36.7	17.1	30.0	9.9

Administrators' awareness of the NAE reports did not differ significantly by institution size. Administrators' familiarity with *The Engineer of 2020* and *Rising above the Gathering Storm* did, however, differ significantly by institution type ($p=.029$ and $p=.013$, respectively). Post-hoc tests indicated that administrators at research universities were more familiar with both *The Engineer of 2020* and *Rising above the Gathering Storm* than those at master's institutions. No significant differences existed between administrators at bachelor's institutions and the other types of institutions. Administrators at the different types of institutions did not differ in their familiarity with *Educating the Engineer of 2020* (p=.121).

When examining just the "big five" engineering disciplines (chemical, civil, electrical, industrial, and mechanical engineering), the program chairs' familiarity with the reports did not differ by discipline. This analysis did not include biomedical/bio-engineering and general engineering due to the small number of respondents in the sample.

Liberal Education in the Engineering Curriculum

Overall, associate deans and program chairs differed very little in their level of agreement on the importance of, and need for, greater curricular breadth and emphasis on liberal education goals in the undergraduate engineering curriculum (see Table 4). One-way analyses of variance of the group means in the distributions in Table 4 identified no statistically significant differences between associate deans and program chairs on any of the seven attitudes explored in this study.

Associate deans and program chairs also held similar opinions regarding the role of humanities and social science courses in preparing engineers. None of the respondents disagreed with the statement that "humanities and social science courses are very important in preparing engineers." In fact, 93 percent of the associate deans and 90 percent of the program chairs agreed or strong agreed with the statement (Table 4). A similar pattern is apparent in respondents' attitudes toward the inclusion of interdisciplinary learning both inside and outside the engineering curriculum. Ninety percent of the associate deans and 83 percent of program chairs either agreed or strongly agreed that interdisciplinary learning should be part of the engineering curriculum. All of the associate deans and the 9 of 10 program chairs also agreed or strongly agreed that undergraduate engineering curriculum should teach students to consider all relevant factors (e.g., social, cultural, environmental) in designing solutions. Ninety three percent of associate deans and 85 percent of the chairs either agreed or strongly agreed that ethical issues should be addressed in multiple (rather than single) courses.

Support for the inclusion of instruction in intercultural communication and preparation for community leadership was more mixed and more moderate for both topics. Sixty-three percent of the associate deans surveyed agreed or strongly agreed that undergraduate engineering curricula should teach students about intercultural communication, whereas only half of the program chairs shared that belief. About a quarter of the associate deans (23%) and more than a third of program chairs (34%) were unsure ("neither agree nor disagree") about whether intercultural communication should be part of the curriculum; a substantial number, however, stated that it should not (13% of the associate deans and 16% of the chairs). Almost three-fourths of the associate deans (73%) and more than two thirds of the program chairs (68%) surveyed agreed or strongly agreed that preparing students to assume community leadership roles should be part of the engineering curriculum. About a quarter of the associate deans (23%) and the chairs (26%) were unsure of engineering's role in preparing community leaders.

Table 4. Administrators' Attitudes toward Liberal Education Emphases.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Mean	Standard Deviation
Humanities and social science courses are very important in preparing engineers							
Associate Dean (n=29)	30.0%	63.3%	6.7%	0.0%	0.0%	4.23	.57
Program Chair (n=81)	22.2	66.7	11.1	0.0	0.0	4.11	.57
Interdisciplinary learning – inside and outside engineering – should be part of the engineering curriculum							
Associate Dean (n=29)	23.3	66.7	10.0	0.0	0.0	4.13	.57
Program Chair (n=80)	12.5	70.0	12.5	5.0	0.0	3.90	.67
Undergraduate engineering curriculum should teach students about intercultural communication							
Associate Dean (n=29)	16.7	46.7	23.3	6.7	6.7	3.60	1.07
Program Chair (n=82)	6.1	43.9	34.1	13.4	2.4	3.37	.88
Undergraduate engineering curriculum should teach students to consider all relevant factors (e.g., social, cultural, environmental) in designing solutions							
Associate Dean (n=29)	26.7	73.3	0.0	0.0	0.0	4.27	.45
Program Chair (n=82)	23.2	67.1	9.8	0.0	0.0	4.13	.56
Undergraduate engineering curriculum should prepare students to assume community leadership roles							
Associate Dean (n=29)	23.3	50.0	23.3	0.0	3.3	3.90	.88
Program Chair (n=82)	17.1	51.2	25.6	4.9	1.2	3.78	.83
Undergraduate engineering curriculum should address ethical issues in multiple courses							
Associate Dean (n=29)	43.3	50.0	0.0	6.7	0.0	4.30	.79
Program Chair (n=82)	18.3	67.1	14.6	0.0	0.0	4.04	.58
Undergraduate engineering curriculum should provide opportunities for students to prepare for occupations other than engineering (e.g., business, medicine, law)							
Associate Dean (n=29)	23.3	43.3	33.3	0.0	0.0	3.90	.76
Program Chair (n=81)	16.0	40.7	29.6	9.9	3.7	3.56	1.00

The majority of the associate deans and program chairs agreed or strongly agreed that the undergraduate engineering curriculum should provide opportunities for students to prepare for occupations other than engineering (e.g., business, medicine, law), although program chairs were more mixed in their support for this proposition. Sixty-seven percent of the associate deans and 57 percent of the program chairs surveyed either agreed or strongly agreed with this position (Table 4). Program chairs were more variable in their opinions on this issue than on any of the other curricular recommendations.

While we hypothesized that industry experience might influence associate deans' and program chairs' perspectives regarding curricular breadth and liberal learning in engineering education, the correlation coefficients (all $\leq |.01|$, statistically non-significant when using two-tailed tests) suggest little or no such relationship. Similarly, tests indicated no significant correlations between years of engineering industry work experience and familiarity with the NAE reports.

An examination of the relationship between institution size and administrators' attitudes toward curricular breadth and liberal education items revealed only one significant relationship, that between institutional size and administrators' attitudes about the importance of humanities and social science courses in the preparation of engineers ($F = 4.62$, $df = 2,108$, $p = .012$).

Administrators at medium-size institutions, compared to those at large institutions, reported a higher level of agreement that humanities and social science courses are important in the preparation of engineers (difference in means = .32). Administrators at small institutions did not differ significantly from those at medium or large institutions regarding the importance of humanities and social sciences in preparing engineers.

With respect to institutional type, significant differences existed only in attitudes toward the need for engineering curricula to prepare students for occupations other than engineering. Post-hoc tests suggest that engineering administrators at research universities, compared to their counterparts at master's institutions, reported higher levels of agreement that the curriculum should prepare students for occupations other than engineering (difference in means = .66; $F = 4.511$, $df = 2,108$, p-value = .013). Administrators at bachelor's institutions did not differ from administrators at the other types of institutions in their views on this item. Administrators' opinions on liberal education in the curriculum did not differ based on their institution size or type for any of the other propositions explored in this study.

Discussion

While the majority of program chairs and associate deans reported having at least some exposure to summaries of the NAE reports, associate deans were far more likely than program chairs to have explored the reports in depth. This finding is not surprising given the associate deans' responsibility for engineering education across disciplines. Despite program chairs' lower levels of familiarity with the NAE reports, however, their support for the liberal education components of the reports is still relatively high (albeit not as high as that of the associate deans). Although the NAE reports focus predominantly on undergraduate education, our findings do indicate that some institutional type-related differences in program chair's familiarity with two of the reports. Chairs at research institutions are more familiar with *The Engineer of 2020* and *The Gathering Storm* reports than do their counterparts at master's institutions, suggesting that the NAE's message may have been more effectively disseminated among research institution leaders than among their peers at master's institutions. However, in light of the overall findings, this discrepancy does not appear to indicate that the message is not getting out to all types of institutions.

Most administrators, whether associate deans or program chairs, appear to support the NAE's vision. The evidence lies in both groups' attitudes toward the need for curricular breadth and liberal education goals and objectives. Specifically, most respondents indicated moderate to strong support for:

- The importance of humanities and social science courses in the preparation of engineers;
- The inclusion of interdisciplinary learning – inside and outside the curriculum;
- The need for undergraduate engineering curricula to develop students' intercultural communication skills;
- Promoting students' awareness of the importance of considering all of the relevant factors that influence design solutions;
- The need for engineering curricula to prepare students for roles as community leaders;

- Including discussion of ethical issues in multiple courses; and
- Preparing students for occupations other than engineering.

The study's findings suggest that the opinions of engineering education administrators – both associate deans of undergraduate education and program chairs – are well-aligned with the goals of the National Academy as they relate to broadening engineering education. Of the attitudes explored in this study, administrators were least enthusiastic (although still supportive) of including instruction in intercultural communication and preparation for community leadership in the engineering curriculum. Administrators may place less importance on intercultural communication because they consider technical communication more foundational. It may also be that administrators have not fully accepted the importance NAE and others have placed on the globalization of the engineering workplace. Similarly, administrators may also see the preparation of community leaders as beyond the purview of engineering programs or simply as a platitude that is not particularly relevant in an engineering curriculum. Generally speaking, however, both associate deans and program chairs support the inclusion of liberal education components in the engineering curriculum.

The one exception to the finding that institution type does not appear to influence associate deans and program chairs' attitudes toward liberal education goals involved the proposition that the engineering curriculum should provide opportunities for students to prepare for occupations other than engineering. Administrators at research institutions may be more likely than those at master's institutions to agree with this proposition because of their institutions' focus on graduate education. Faculty members often make a distinction between the skill sets and experiences necessary to prepare baccalaureate students to enter the engineering workforce and to enter graduate school. This perception may lead administrators who are more experienced with graduate programs to see the value in preparing students to use the tools of inquiry to meet various professional needs, rather than focusing solely on preparation for a single profession.

On the whole, associate deans' and chairs' attitudes toward liberal education do not appear to vary with the type or size of the institution in which they work. Nor do program chairs' attitudes vary with their engineering discipline. These findings indicate substantial agreement on these educational goals across disciplines and on engineering curricula across institutions. This consensus may have been promoted by ABET's EC2000 Criterion 3.a-k accreditation requirements. The EC2000 criteria embrace many of the fundamental principles advanced in the NAE reports, although the reports place greater emphasis on liberal education dimensions than do the ABET criteria. Taken together, the findings suggest, first, that the ideas associated with the NAE reports are fairly widespread among engineering education leadership, even if not all administrators have received them from the same source, and second that administrators generally support the goals outlined in the E2020 reports. What we cannot determine in this study is the extent to which the ideas and goals associated with the E2020 reports were already prominent among associate deans and program chairs when the NAE reports were published.

Conclusions and Future Analyses

This study demonstrates that substantial support exists among administrators for integrating the goals of liberal and professional education in the undergraduate engineering curriculum.

Associate deans and program chairs both appear to view liberal learning as a path by which engineering students can be prepared to be productive professionals, community citizens, and leaders in a diverse, global, and technologically and socially dynamic world. Administrators' attitudinal support for liberal engineering education is encouraging in that beliefs are often a precursor of action.[26, 27, 28] In addition, program chairs and associate deans for undergraduate education are uniquely positioned to initiate curricular and programmatic reforms. These leaders often have strong influence over a unit or program's curricular content and sequence. Administrators might also have influence among other administrators and faculty members involved in college, program, and/or course-level curricular revision and instruction. Moreover, the evident support for liberal learning evident in the study's findings is relatively consistent regardless of size or type of administrators' institutions, although associate deans are more familiar than program chairs with the details of the NAE reports articulating those goals. Overall, however, the evidence clearly indicates that the E2020 report goals are broadly accepted, although the dissemination paths by which the message is reaching associate deans and program chairs may vary.

Curricular change may be mandated from the top of an institution's organizational chart, but reform must be enacted from the bottom up. While the NAE and engineering administrators may agree upon educational goals, it is the role of faculty members to implement such goals. Given the high level of faculty curricular autonomy characteristic of American higher education, little substantive change is likely without faculty support. While this study reveals substantial agreement at the top, the next critical steps will be to analyze data already collected from engineering faculty that explore 1) faculty attitudes toward liberal learning, 2) the extent of their incorporation of liberal education goals into their courses, 3) their instructional approaches that may emphasize liberal learning outcomes, and 4) their perceptions of their responsibilities for promoting liberal learning in their courses. The final steps will be to examine the role of administrators and faculty in teaching and emphasizing these goals in the curriculum and its influence on student liberal learning. Only with these pieces of the puzzle will we be able to fully understand the current status of liberal learning in engineering education.

Bibliography

[1] National Academy of Engineering. (2004). *The engineer of 2020: Visions of engineering in the new century*. Washington, DC: National Academies Press.

[2] National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, DC: National Academies Press.

[3] American Society for Engineering Education. (1994). *The Green report: Engineering education for a changing world.* Joint project report of the Engineering Deans Council and the Corporate Roundtable of the ASEE. Retrieved November 14, 2009 from http://www.asee.org/resources/beyond/greenReport.cfm.

[4] ABET. *Engineering criteria 2000.* Baltimore, MD: Author.

[5] National Academy of Engineering and Institute of Medicine. (2007). *Rising Above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

[6] Galloway, P. D. (2008). *The 21st Century Engineer: A proposal for Engineering Education Reform*. Reston, VA: American Society of Civil Engineers Press.

[7] Sheppard, S. D., Macatangay, K., Colby, A. & Sullivan, W. M. (2008) *Educating Engineers: Designing the Future of the Field*. San Francisco: Jossey-Bass.

[8] Duderstadt, J. J. (2009). *Engineering for a changing world: A roadmap to the future of engineering practice, research, and education.* Ann Arbor, MI: The Millennium Project.
[9] Reuben, J. A. (1996). *The making of the modern university: Intellectual transformation and the marginalization of morality*. Chicago: University of Chicago Press.
[10] Rudolph, F. (1977). *Curriculum: A history of the American undergraduate course of study since 1636.* San Francisco: Jossey Bass.
[11] Geiger, R. L. (1999). The ten generations of American higher education. In P. Altbach, R. O. Berdahl & P. J. Gumport (Eds.), *The American higher education in the 21st century: Social, political, and economic challenges* (pp. 38-69). Baltimore: Johns Hopkins University Press.
[12] Rothblatt, S. (1988). General education on the American campus: A historical introduction in brief. In I. Westbury and A. C. Purves (Eds.), *Cultural literacy and the idea of general education: Eighty-seventh yearbook of the National Society for the Study of Education* (pp. 9-28). Chicago: University of Chicago Press.
[13] Conrad, C. F., & Wyer, J. C. (1980). *Liberal education in transition* (ERIC Research Report No. 3.) Washington, DC: American Association for Higher Education.
[14] Hutchins, R. M. (1936). *The higher learning in America*. New Haven: Yale University Press.
[15] Ehrlich, T. (1997). Dewey versus Hutchins: The next round. In R. Orrill (Ed.), *Education and democracy* (pp. 225-262). New York: The College Board.
[16] The Harvard Committee on the Objectives of a General Education in a Free Society (1945). *General education in a free society: Report of the Harvard Committee*. Cambridge, MA: Harvard University Press.
[17] Association of American Colleges and Universities. (2007). *College learning for the new global century: A report from the National Leadership Council for Liberal Education*. Washington, DC: Association of American Colleges and Universities.
[18] Stark, J. S. and Lowther, M.A. (1988). *Strengthening the ties that bind: Integrating undergraduate liberal and professional education*. Ann Arbor: Regents of the University of Michigan.
[19] Shulman, L. S. (1997). Professing the Liberal Arts. In R. Orrill (Ed.), *Education and democracy: Re-imagining liberal learning in America*. New York: The College Entrance Examination Board.
[20] American Society for Engineering Education. (2009). *Creating a culture for scholarly and systematic innovation in engineering education : Ensuring U.S. engineering has the right people with the right talent for a global society* (2009). Washington, DC: American Society for Engineering Education.
[21] *Prototype to production* (n.d.). Retrieved November 14, 2009 from http://www.ed.psu.edu/educ/e2020/p2p
[22] *E2020 survey instruments* (n.d.). Retrieved November 14, 2009 from http://www.ed.psu.edu/educ/e2020/surveys-1
[23] *Prototyping the engineer of* 2020. (n.d.). Retrieved November 14, 2009 from http://www.ed.psu.edu/educ/e2020/p360
[24] Dillman, D. A., Smyth, J. D., & Christian, L. M. (2009). *Internet, mail, and mixed-mode surveys: The tailored design method* (3rd ed.). Hoboken, NJ: Wiley.
[25] National Center for Educations Statistics, (2004). 2005 Carnegie Classification; IPEDS Institutional Characteristics and Fall Enrollment.
[26] Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332.
[27] Prawat, R. (1992). Teachers' beliefs about teaching and learning: A constructivist perspective. *American Journal of Education, 100* (3), 354-395.
[28] Trigwell, K., & Prosser, M. (1996). Congruence between intention and strategy in university science teachers' approaches to teaching. *Higher Education, 32*(1), 77-87.