Why Raise the Education Bar for Civil Engineers?

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Introduction

In October of 2001, the Board of Direction of the American Society of Civil Engineers (ASCE) unanimously voted to revise and move forward with Policy Statement 465, entitled "Academic Prerequisites for Licensure and Professional Practice." This policy "supports the concept of the Master's degree or Equivalent as a prerequisite for licensure and the practice of civil engineering at a professional level."[6] The revised policy, a version of which was first accepted by the Board in 1998, is expected to enhance the prestige, image, compensation, and qualifications of the profession, as well as public health, safety, and welfare. To accomplish this, the policy identifies stakeholders and their responsibilities:

> *ASCE encourages institutions of higher education, governmental units, employers, civil engineers, and other appropriate organizations to endorse, support, and promote the concept of mandatory post-baccalaureate education for the practice of civil engineering at a professional level. The implementation of this effort should occur through establishing appropriate curricula in the formal education experience, appropriate recognition and compensation in the workplace, and congruent standards for licensure*.[6]

The purpose of this paper is to better define the broad issues necessitating an increase in education. The ASCE Task Committee on the First Professional Degree has identified nine such issues, presented in Figure 1.[36] The three issues at the top of the figure—slippage in education and licensure requirements relative to other professions, reduction in credit hours, and relatively low compensation—have been discussed in previous papers by the first three authors.[29, 30, 31, 32, 33] This paper will address the remaining six issues as the basis to move forward to raise the educational bar in civil engineering.

Leadership Preparation

Civil engineers are not commonly perceived as leaders outside of their specialized technical communities. In a recent special issue, *Time Magazine* named the most influential "Builders and Titans of the 20th century."[12] Among such varied luminaries as Henry Ford and Walt Disney, only Stephen Bechtel represented the ranks of civil engineers. Whereas "star" architects such as I.M. Pei, Frank Gehry, Ceasar Pelli, and Santiago Calatrava are commonly celebrated in the media as visionaries and their projects given front-page, color representation, civil engineers are rarely even mentioned by name and their projects hardly touted.[38] A recent poll supports the supposition that civil engineers are not commonly perceived as leaders. The poll was commissioned by the American Council of Engineering Companies (ACEC), an association representing consulting engineering firms, and queried business leaders; federal, state, and local legislators and authorities; utilities and Department of Transportation (DOT) officials; media representatives; and engineering students. Only 14% of respondents viewed consulting engineers as community leaders, while 45% viewed them as technical consultants.[17]

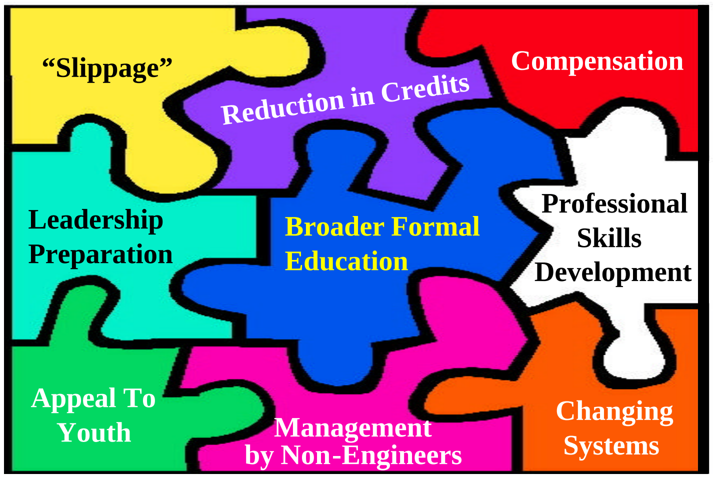


Figure 1—Nine Issue Facets

Civil engineering is not *intentional* about educating students to become leaders in society, and it is precisely the quality of strong leadership that must distinguish civil engineering in the 21st century. Leadership is a complicated notion that includes the art and science of providing direction and vision to an organization, communicating that direction, and motivating others to buy-in and contribute to the realization of that vision. Leadership can be based on, but is not the same thing as, technical expertise. Civil engineers are unquestionably leaders in the technical aspects of designing buildings, public works facilities, and highways. But few engineers in general, and few civil engineers in particular, seek or gain leadership positions outside of their technical specialties. Only two Presidents have been engineers, Presidents Herbert Hoover (mining engineer) and Jimmy Carter (nuclear engineer), and currently, there are only two licensed engineers in Congress—Rep. Joe Barton, P.E. (R-TX-06) who holds a B.S. degree in engineering from Texas A&M University and a Master's degree in industrial administration, and Rep. John Hostettler, P.E. (R-IN-08) who holds a B.S. degree in mechanical engineering from Rose-Hulman Institute of Technology.[25] Furthermore, as will be discussed below, engineers are being passed up for executive and management positions, often for people with a Masters of Business Administration or law degree—professional disciplines with strong leadership and management training.[10, 15, 36]

The value of leadership is not explicitly communicated to students as a priority of their education. The writer-engineer Samuel Florman has observed that most engineers do not gain an appreciation for leadership—or literature, philosophy, and history—until they are deep into their careers.[16] This is hardly surprising: a marginal, almost negligible percentage of the civil engineering curriculum is focused on leadership. Yet even in the most technical positions, civil engineers must be aware of such issues as cost accounting, taxation, liability, safety, quality control, marketing, and client relations—concerns central to leadership and management. Without training in the fundamentals of leadership and management, it is little wonder that so few civil engineers become leaders within greater society. Yet the insight and understanding that civil engineers possess could immeasurably enhance the public dialogue on crucial issues facing the 21st century such as sustainability and environmental protection.

This issue is sensitive and complicated given that many academics and practitioners are defensive about what constitutes leadership and how to integrate it into the classroom. Moreover, a common belief is that leadership cannot be taught but is instead an inherent gift that you either do or do not possess. Crucial components of effective leadership such as proper speaking, articulate writing, active listening, skillful negotiating, and efficient time management can be taught and are imparted through university courses, workshops, and publications such as *ASCE Leadership and Management in Engineering* and *Harvard Business Review*, both of which regularly publish articles on effective leadership.[18, 19, 21] The problem is that leadership skills are not consistently taught to civil engineering students. To be sure, some students participate in student organizations such as the American Society of Civil Engineers, Chi Epsilon, and Tau Beta Pi, where they receive first-hand exposure to leadership. A few students even participate in formal leadership courses, camps, and workshops sponsored by organizations such as Leadershape™ (www.leadershape.org). On the whole, however, civil engineering programs and student organizations are not intentional about developing leaders within society. Without intending to teach the value and importance of leadership, as well as the skills and techniques necessary to realize leadership, is it any wonder that civil engineers are viewed almost exclusively as technical experts?

Broader Formal Education

Leadership is intricately bound up in the values, norms, and history of a society and culture. As such, it is difficult to lead without a broad knowledge of the literature, philosophy, history, politics, and technology of that society. Cultural critics such as Neil Postman and Allen Bloom have written poignantly and persuasively on the need for a well-rounded education in the humanities and sciences in order to think creatively, critically, and responsibly.[9, 28] In his book *The Civilized Engineer*, Samuel Florman cites countless examples of scientists and engineers whose education in, and passion for, the liberal arts led to breakthrough discoveries and world-changing ideas.[16] From Isaac Newton to Albert Einstein to Thomas Edison to Washington Roebling, Florman recounts the ways in which the forms of music, painting, and philosophy have helped structure thought and enhance an individual's problem solving abilities. In his article "How Creative Engineers Think," Tom Peters explores the creative problem solving of leading engineers such as Gustave Eiffel.[26] Based on archival data, Peters determines that many groundbreaking design concepts stem from simple, often sublime reformulations of current thinking and practice, and that these breakthroughs are often fed by study and observation outside of engineering paradigms.

A broad, holistic education has been shown to increase creativity and the ability to solve complex problems. Such appreciation and understanding can be taught to undergraduates, and is being taught in many literature, philosophy, history, language, math, music, and social science courses. As with leadership skills, however, civil engineering students have little exposure to the liberal arts. This has not always been the case. Engineering students in the 19th century took significant literature, composition, foreign language, geography, and economics, as well as physical science courses. Figure 2 presents a sample three-year curriculum offered in 1852 at Rensselaer Polytechnic Institute, an early and leading engineering school, that demonstrates a broad, liberal arts-based education.

	Departments of Instruction.	Subjects of Study and Practical Exercises.
FIRST YEAR.		
DIVISION C—THIRD CLASS.	MATHEMATICS.	Algebra.—Elementary Geometry.—Nature and use of Logarithmic and Trigonometric Tables.—Trigonometry.—Mensuration.
	PHYSICS.	General Properties of Matter.—Nature of the Physical Forces.—Phenomena and Laws of Gravity.—Phenomena and Laws of Heat.
	GRAPHICS.	Use of Drawing Instruments.—Graphical Constructions of Chain and Compass Surveys.—Copying of Mechanical Drawings.
	CHEMISTRY.	Principles of Chemical Philosophy.—Study of the Non-Metallic Elements.—Laboratory Practice.
	GEODETICAL ENGINEERING.	Operations in the Field.—Measuring of Lines; Chain and Compass Surveys of Fields and Farming Estates; Dividing Land.—Computations of Areas, etc.—Mapping of Surveys.
	PHYSICAL GEOGRAPHY.	Structural and Systematic Botany.—Vegetable Physiology.—Geographical Distribution of Plants.
	ENGLISH COMPOSITION AND CRITICISM.	Section Lecture Exercises with Criticisms.—Keeping of Lecture Books.—Writing of Special Theses, etc.
	FRENCH LANGUAGE.	Elements of *French Grammar.*—French Exercises and Translations.
SECOND YEAR.		
DIVISION B—SECOND CLASS.	MATHEMATICS.	Analytical Trigonometry.—Analytical Geometry.—Differential Calculus.—Integral Calculus.
	PHYSICS.	Terrestrial Magnetism.—Statical and Dynamical Electricity.—Electro-Magnetism.—Magneto-Electricity.—Acoustics.—Optics.
	GRAPHICS.	Descriptive Geometry.—Measuring and Sketching Engineering and Architectural Structures, and Construction of Working Drawings from these data.—Topographical Drawing.
	CHEMISTRY.	Chemical Study of the Metals.—Exercises in Qualitative Analyses.
	GEODETICAL ENGINEERING.	Theory and Adjustments of Field Instruments.—Trigonometrical Determination of Heights and Distances.—Field Exercises in General Geodetic Operations.—Field Practice in Hydrographical Surveying.
	GEOLOGY.	Descriptive Mineralogy.—Systematic and Descriptive Geology.—Economic Geology.
	ENGLISH COMPOSITION AND CRITICISM.	Section Lecture Exercises with Criticisms.—Writing out of General Lectures.—Writing of Theses on Scientific and Practical Subjects.
	FRENCH LANGUAGE.	Double Translations, (French and English.) Reading of French Scientific Authors.
THIRD YEAR.		
DIVISION A—FIRST CLASS.	RATIONAL MECHANICS.	General Statics and Dynamics of Solids, Liquids, and Gases.
	PRACTICAL ASTRONOMY.	Investigation of Astronomical Principles and Data for the solution of the Practical Problems of the *Meridian, Time, Latitude,* and *Longitude* of a place.—Sextant and Transit Observations, including Computations for, and Reductions, made by students.
	CONSTRUCTIVE ENGINEERING.	Equilibrium and Stability of Architectural and Engineering Structures.—Materials for Construction.—Theory of Machines.—Road Engineering.—Hydraulic Engineering.—Steam Engine and Hydraulic Motors.
	GEODETICAL ENGINEERING.	Higher Geodetic Surveying of Extensive Areas by Trigonometrical and Astronomical Methods.—Topographical Surveying, with Field Practice, Reductions, and Construction of Maps.—Surveys, Location, etc., of Engineering Works.
	PRACTICAL CHEMISTRY AND PHYSICS.	Chemical Study of the Principal *Economic Minerals*:—Blow-pipe Examinations.—Practical Exercises in Determining the Specific Gravities of Solids, Liquids, and Gases.
	PHYSICAL GEOGRAPHY.	Meteorology, General Hydrology, and Topography of the Earth's Surface.—Distribution of Plants and Animals.—Relations of Physical Geography to Engineering Works of Inter-Communication.
	GRAPHICS.	Descriptive Geometry, embracing Projections of Shades and Shadows, and the Principles and Practice of Natural and Isometrical Perspective.—Sketching of Machines, and Construction of Working Drawings of same.—Topographical Drawing.—Drawing Maps and Sections of Surveys for Lines of Transit.
	ENGLISH COMPOSITION AND CRITICISM.	Section Lectures,—*Extemporaneous* and *Written*,—with full Criticisms.—*Written Reviews* of Machines, Structures, and Processes in the vicinity of Troy.—*Scientific* and *Practical Theses.*

Figure 2—Curriculum at Rensselaer Polytechnic Institute,1852

Early engineering programs were modeled on the French system, which centered on theory. Students primarily took math, science, and liberal arts courses until their last semesters, wherein they learned the basics of engineering technology and design. It was an assumption that upon graduation students would learn the art of engineering in the field; university education was primarily intended to broadly educate the individual and teach the underpinning fundamentals necessary to appreciate and apply engineering technology. Students were therefore taught the social and physical systems that form the context of engineering practice *before* learning how to apply specific engineering technologies.

Throughout much of the 19th century there were primarily two branches of engineering—military and civil. As civil engineering matured, and as sub-fields such as mechanical and electrical began to splinter off in the late 19th and early 20th century, education became more specialized and technical. As these individual fields matured, specific curricula relying ever more on technology and practice became the norm, resulting in the current highly technical civil (and mechanical and electrical and computer and materials) engineering curriculum. Until very recently, only around 12.5%, or one college semester, of the typical civil engineering curriculum is composed of liberal arts, while the total number of credits required for a bachelor's degree is shrinking.[29]

All civil engineers can benefit from studying the liberal arts, as this leads to better communication, enhanced creativity, richer understanding of differing perspectives, and an appreciation of aesthetic properties of design. Unfortunately, few civil engineering programs teach students to value and pursue an understanding of the liberal arts. Encouragingly, the Accreditation Board of Engineering and Technology (ABET), the accrediting body for undergraduate engineering programs, has recently recognized the need for a broad, liberal arts-based education. ABET has formally promulgated 11 outcomes for undergraduate engineering programs, at least six of which are related to the liberal arts.[1] These outcomes are presented in the following list, with the six relating to the liberal arts in boldface:

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; and
k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Without significant education reform at the most basic level, it is difficult to imagine any undergraduate curriculum in the country meeting the spirit of these new requirements. Without a significant overhaul of current education, however, it is equally difficult to imagine civil engineers as a group transcending their technical expertise to become leaders in society. To truly embrace ABET's 11 outcomes, most collegiate programs will have to significantly increase their liberal arts content, or better yet, make the liberal arts the curricular base. This will not be an easy task, especially considering several states are mandating a maximum number of credits in the 120-128 range. Most universities will have to make some tough decisions regarding resources, program direction, and balance of technical, leadership, and liberal arts content. In their on-going effort to reform, education programs can look to institutions such as Dartmouth College, which requires civil engineering students to take 15 liberal arts courses—almost a third of the total undergraduate curriculum. Dartmouth College offers a five-year program, which is presented in the Appendix A. Programs such as this one that promote holistic education will serve as one possible model for the implementation of Policy 465.

Professional Skills Development

For some time now, leading universities have recognized the bachelor's degree for what it is: pre-professional preparation. Within the civil and environmental engineering program at Stanford University, for instance, "at least one year of graduate study is strongly recommended for professional practice" (http://www-cive.stanford.edu/programs.html#Overview). To successfully manage the complex, inter-dependent systems surrounding projects, civil engineers of 2030 will require knowledge not typically offered in today's Bachelors of Science in Civil Engineering (BSCE). The professions of accountancy, occupational therapy, and pharmacy have recognized the complexity and knowledge growth in their fields and in greater society. In response, each profession has recently called for education beyond the bachelor's degree.[33] Civil engineering is at least as complex as any of these fields; should not the education of its future professionals reflect this?

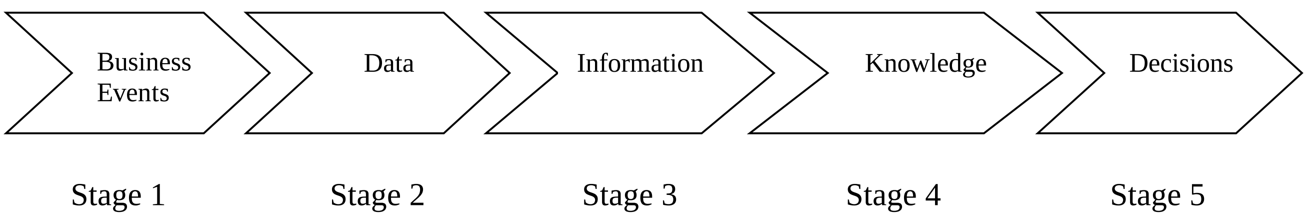
The interrelatedness of today's world touches almost everyone, especially those who manage change, which is to say leaders. From the start of their careers, civil engineers of 2030 will be expected to know more about an increasingly complex world without the job security enjoyed by previous generations.[36] In the global, internet-connected economy with inexpensive engineering services available 24 hours a day, there will be less incentive for employers to develop employees.[14, 24] The leading companies will, as they always have, invest in the education and training of employees, but civil engineers will be forced to become entrepreneurial in the planning and management of their careers from the very start. This will be all the more challenging to the next generation unless current education moves beyond the focus on technical aspects of civil engineering.

The profession has been moving toward technical specialization for some time now, but a broad-based curriculum and understanding of the entire field would serve novice and veteran civil engineers alike.[7, 8, 34] To empower civil engineering students for a bright future, additional knowledge of communications, leadership, teamwork, environmental science, liberal arts, business, and management will also be necessary.[2, 20] This rich complement of skills and understanding will better prepare the next generation of professionals to succeed in the dynamic field of civil engineering and provide much needed guidance and leadership for greater society. Organizations such as ABET have begun defining what this core body of knowledge for civil engineering should be, but the profession at large must become actively involved in this significant effort. The civil engineering community as a whole must help redefine the core skills, competencies, and outcomes necessary to practice at the professional level.

Declining Appeal to Youth

Civil engineering, as well as the other engineering disciplines, suffers from an image problem. While a recent Harris Poll revealed that engineers were held in “very great” or “considerable” prestige by 73% of the population, the general public does not fully appreciate what engineers accomplish because the general public does not seem to know what engineers do.[23, 35, 38] The Harris Poll, conducted in 1998, found that over 60% of Americans are “not very” or “not at all well” informed about engineers and engineering. While 40% of males are not well informed about engineers, over 80% of females do not readily know what it is that engineering is all about.[35] Furthermore, a poll conducted for ACEC revealed that 22.9% of state legislators and media representatives have “no clear conception” of what consulting engineers do, while 54.3% of media representatives, 45.7% of federal legislators, and 36.1% of business leaders “do not know” the position of the consulting engineer within larger society.[17] This image problem directly hinders the attraction and retention of quality students to the profession—a trend that could have serious consequences on the future of civil engineering.

Civil engineering is not the only profession that is having difficulty attracting top students. In a sobering report entitled “Accounting Education: Charting the Course Through a Perilous Future,” the nation’s leading accounting firms and societies presented a critical assessment of current education and practice.[3] Among other conclusions, this report recognized that accounting education is overly technical and obsolete, which Figure 3 helps explain. This “value chain” presents five stages of business activity and the corresponding value in today’s economy.



- Stage 1 activity is now worth no more than $10 per hour
- Stage 2 activity is now worth no more than $30 per hour
- Stage 3 activity is now worth $100 per hour
- Stage 4 activity is now worth $300 per hour
- Stage 5 activity is now worth $1,000 per hour

Figure 3—Value Chain[3]

According to the “Accounting Education” study, accounting students focus on Stage 1 and Stage 2 activities instead of learning how to add value at higher stages of the chain.[3] Current education negatively affects the accountant’s compensation in the workplace, as well as hinders advancement opportunities. To lead and manage effectively, a systems or global understanding is essential—an understanding that is not commonly imparted in today’s undergraduate accounting or civil engineering programs. As such, accountants—and civil engineers—are commonly passed over for promotion.

Another informative study, commissioned by the American Institute of Certified Public Accountants (AICPA), offers the hopeful conclusion that high-school and college students want to do challenging and meaningful work in their professional careers.[37] According to the AICPA survey, most high school and college students believe they need an advanced degree to succeed. Fully 76% of high-school students and 80% of college students expect to attend graduate school in order to pursue their careers, while an "overwhelming majority" plan to seek the same career regardless of the educational requirements.[37] Quite simply, students will go to school for a profession that they perceive as having value.

From this data, it would appear that increased education does not diminish appeal to prospective students. For civil engineering this is good news: prospective students would not necessarily view an increase in the length of education as an obstacle. Also encouraging is the information presented in Columns 2 and 3 of Table 1. According to the AICPA survey, engineering is a profession about which students have a high opinion.[37] Unfortunately, engineering is not generally perceived as a profession worth pursuing by a majority of college students, as Column 5 makes abundantly clear. While engineering is "worth the extra effort" to high school students, there is a 33% drop in perceived value from high school to college.

Table 1. Student Perceptions of Professions[37]

Professions (1)	High Opinion		Careers "worth the extra effort"	
	High school (2)	College (3)	High School (4)	College (5)
Doctors	78%	85%	90%	92%
Lawyers	45%	38%	71%	77%
Teachers	66%	83%	70%	81%
Engineers	**58%**	**72%**	**68%**	**35%**
Accountants/CPA	30%	36%	40%	47%

Year 2000 sample size: 1000 high school students, 1174 college students

A logical conclusion to draw from the AICPA study is that students are somehow turned off by engineering courses or curricula; the culture of engineering programs; and/or by the image and perceived standing of the profession. While engineering is certainly a worthwhile field, it is not perceived as worth the extra effort to a majority of college students (65%). Again, like defining the body of knowledge necessary in civil engineering, it is incumbent upon the profession to determine why the profession is unattractive to college students, and how this can be changed.

Management by Non-Engineers

As mentioned above, very few civil engineers rise to prominence in public service. In and of itself this may not be of significant concern, but when coupled with the fact that non-engineers are increasingly managing and leading civil engineers, as well as occupying prestigious positions once held by civil engineers, the trend becomes troublesome.[34]

Table 2 presents some surprising information about a class of public positions that have historically been occupied by civil engineers: state secretaries of transportation. This table shows the professional education of each current state transportation secretary, including that of Washington D.C. As of January 2002, only 18 secretaries had bachelor's degrees in civil engineering. One additional secretary without a BSCE had earned a master's degree in civil engineering, putting the total of secretaries trained in civil engineering at 19, or only 37%. What is encouraging is that 27 state secretaries of transportation, or 53% of the total, hold at least one advanced degree. This is a strong indication that additional education corresponds with positions of leadership.

Table 2. Degrees Held by State Secretaries of Transportation, January 2002 (Includes Washington, D.C.)

Degree Type (1)	Undergraduate (2)	Graduate (3)
Liberal Arts	20	8
Civil Engineering	**18**	**5**
Business/Management	10	7
Public Administration	1	4
Other Engineering	1	2
Law Degree	--	7
Total Degrees	50*	33**
Total Persons Holding a Degree	48	27
No Degrees Held	3	24
Multiple Degrees	2	5
Male to Female Ratio	47/4	

* 48 secretaries hold a total of 50 undergraduate degrees since two secretaries hold multiple degrees
** 27 secretaries hold 33 graduate degrees since four secretaries have two degrees each, while one has three degrees

Equally striking is the information presented in Table 3, which shows the professional education of the national Secretaries of Transportation throughout the history of that position. In the 30 years of this position as the head of the department responsible for the planning, designing, constructing, and maintaining the nation's public transportation infrastructure, only one appointee was an engineer, while nine (9) were lawyers.

Table 3. Educational Background of National Secretaries of Transportation

Degree Type (1)	Number (2)
Law	9
Business/Management	2
Architectural Construction	1
Economics	1
Engineering	**1**
Total	14

According to Janet Ward of *American City & County*, at local and county levels, non-engineers are also garnering positions in public works that were once held exclusively by civil engineers. A study by the American Public Works Association confirms the decline of public works directors with a civil engineering degree. From 1970 to 1980 the number of public works directors holding a civil engineering degree decreased from 50% to 35%.[5] What does it say about a profession when the leading decision-makers come from outside of the profession? Engineering has not always had difficulty producing leaders: as late as 1929, two-thirds of all engineers progressed from technical work to management positions.[39] In the 21st century civil engineers must decide in which direction they wish to proceed: as leading technicians or as leaders of the built environment. With their technical proficiency, civil engineers can add great value to society. They can also become effective leaders—but only if they receive training and education in leadership, liberal arts, communication, and management.[10]

Changing Systems

While civil engineering has always been a social enterprise, social, human, and environmental parameters will increasingly define the application of civil engineering in the 21st century.[27] Taking the most conspicuous example, September 11, 2001 taught the nation that the world is composed of groups that can differ radically in their interpretation of morality, justice, and progress. Civil engineers have always been required to understand the systems that directly influence their projects, including structural and material, but increasingly they must grapple with social influences and systems. This can be a complex endeavor, but it is a necessary one. To succeed in the 21st century, civil engineering projects will require the project team to "comprehend not just the scientific and technological domains, but the social science domains – culture, religion, politics, [and] institutional dynamics." [4] This goes deeper than holding a community information meeting; this goes to the core of the civil engineering endeavor.

Several key attributes of today's world are fundamentally changing the way in which civil engineering is practiced at the professional level. Population growth and related consequences such as increased energy and land use; increased interconnection within human economical and infrastructural systems; increased reliance on information technology; system preservation; and mounting detail contained in building codes, specifications, and standards will continue to challenge civil engineers in the coming decades, necessitating a reevaluation of the fundamental knowledge base of the profession.[4, 11, 13, 33, 36] As natural resources dwindle and the infrastructure grows more intricate, civil engineers will be increasingly called upon to confront the various social, political, environmental, and infrastructural implications of design and construction projects, from planning phases through decommissioning and reconstruction. Tomorrow's civil engineers will have to learn to appreciate and predict with more accuracy the far-reaching consequences of projects in terms of environmental impact, sustainability, and vulnerability. To practice in 2030, the civil engineer will require skills and understanding allowing him or her to navigate through greater uncertainty and to communicate with greater clarity the options and solutions available to the project team and, most importantly, the public. A reorganization of the undergraduate curriculum, along with additional education beyond the BSCE, will ensure that the civil engineer of 2030 has the knowledge, capabilities, and skills to succeed.

Conclusion

What will the civil engineering project of 2030 look like? Many elements will be recognizable, but there will also be unimaginable technologies and complications confronting the future civil engineer. Civil engineers will find a way around whatever problems arise—this is a profession of problem solvers—but to truly take control of the future, the profession must act now. In a cross-national study of the leading professions published in 1996, a leading sociologist determined that engineering "is not in control of the market for [its] services."[22] The same study also revealed that engineers enjoy a "'trusted worker' status, as well as the short-term freedom they have to control their work." The market for civil engineering design and consulting services is not likely to diminish in the 21st century; the only questions are what role civil engineers will play in determining the scope of their contributions and the market value for their services.

The authors believe that a sober look at the current state of affairs, recognizing the issues facing the profession, will result in the conclusion that something must be done to elevate civil engineering and civil engineering education. Specific solutions may differ, but civil engineers must work to define the body of knowledge necessary for professional practice. Enhanced educational prerequisites and a retooled curriculum will allow civil engineers of 2030 to help build, as well as lead, a safer, better society.

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Appendix A: Curriculum for Bachelor of Arts (A.B.) and Bachelor of Engineering (B.E.) in Environmental Engineering at Dartmouth College, Five-year program

<u>Required Liberal Arts Courses</u>

1 English (English 5 or equivalent)
1 Freshman Seminar
3 Foreign Languages
10 Humanities/Social Science distributive courses

Additional Math/Natural Science Course

Engs 190. Project Initiation
Engs 290. Project Completion
Engs 36. Chemical Process Engineering
Engs 42. Contaminant Hydrogeology
Engs 43. Environmental Transport & Fate
Engs 91. Numerical Methods
Engs 156. Heat, Mass, & Momentum
Engs 171. Industrial Ecology
Earth Sciences 66. Hydrogeology

Prerequisites to the Engineering Sciences Major

Mathematics 3. Introduction to Calculus
Mathematics 8. Calculus and Linear Algebra
Mathematics 13. Multivariable Calculus
Physics 13. Introductory Physics I
Physics 14. Introductory Physics II
Chemistry 5. General Chemistry

Engineering Sciences Major Core Courses

Engs 21. Introduction to Engineering
Engs 22. Systems
Engs 23. Distributed Systems and Fields
Engs 25. Thermodynamics
Engs 27. Discrete and Probabilistic Systems
Engs 34. Fluid Dynamics
Engs 37. Environmental Engineering
Engs 41. Environmental & Natural Resource Management
Engs 52. Operations Research
Chemistry 6. General Chemistry

Bachelor of Engineering (B.E.) Program

Engs 190. Project Initiation
Engs 290. Project Completion
Engs 36. Chemical Process Engineering
Engs 42. Contaminant Hydrology
Engs 42. Environmental Transport & Fate
Engs 91. Numerical Methods
Engs 156. Heart, Mass, & Momentum
Engs, 171, Industrial Ecology
Earth Sciences 66. Hydrology

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