Education in Construction Engineering and Management Built on Tradition: Blueprint for Tomorrow

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Abstract: Construction continues to be a significant part of the global economy and shapes the built environment and quality of life for people around the world. In the United States, construction is a multibillion dollar annual enterprise, employing nearly 10 million people. However, it appears that the fragmented nature of the industry continues to hamper productivity and hoped-for gains in efficiency. Issues involve an array of regulatory and legal constructs that: (1) redistribute risk; (2) present only low barriers to entry (making company startup somewhat easy); and (3) fail to provide the quality and quantity of labor necessary. These factors continue to produce overall inefficiencies throughout the construction industry, and ill prepare the industry for the formidable challenges of globalization, sustainability, population growth, and wise use of resources. The purpose of this paper is to review the past and present of construction engineering within the context of civil engineering, and to prescribe practical change to revitalize construction engineering education to meet future demands.

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Evolution of Country and Profession

America has long been known as the land of opportunity. The country, in its formative and developing years, has been a place of opportunity and challenge for those with engaging and enterprising minds, talents, and abilities. As a young nation, the United States relied deeply on engineering, surveying, and construction. No one accepted the challenge or seized the opportunity more so than engineers who built the infrastructures, modern cities, and all the conveniences that shape our contemporary world. The history of the growth of the construction industry and construction education in the United States is a reflection of the growth of America.

In the 19th century, engineers focused their efforts on the transcontinental rail system to link the country from coast to coast. In the 20th century, engineers turned their attention to a growing need for an interstate highway system, safe drinking water, and solutions for evolving environmental problems facing a growing urban society. But, how did these early engineers learn what to do and how to get the job done? It was often a learned trade under a master practitioner or in other instances through trial and error. In other cases, construction was considered a craft that was handed down from father to son through the generations. Over time and due to increasing demands for solutions, formal academic training was increasingly required to meet challenges and solve problems that no one had ever encountered before.

The U.S. Military Academy, founded in 1802 by President Thomas Jefferson, was the first significant source of trained engineers in the early to mid 1800s. When the academy began, and because the country so desperately needed engineers, civil engineering was the foundation of the curriculum. Graduates of the academy went on to work on the country's developing railways, bridges, harbors, and roads. There were many other engineers in practice with little, if any, formal education. "They acquired their technical knowledge through self-study and apprenticeship, often as axmen or rodmen in surveying parties. The roads, canals, and railroads on which they worked were their universities" (Fairweather 2002).

With time, more formal educational programs were developed. The first private engineering school was the Rensselaer Institute of Technology, started by Amos Eaton and Stephen Van Rensselaer in 1835. Construction education itself found its way into the university setting first as a necessary part of many early civil engineering programs. However, as project needs dictated greater levels of specificity and precision, a need grew for more construction-based content than could be found in typical civil engineering programs. For example, it was not until after World War II that construction was first formalized as an engineering discipline at Texas A & M University, in 1946, to be joined in following years by programs at universities such as Stanford University, Massachusetts Institute of Technology, the University of

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Mississippi, North Carolina State University, and the University of Michigan.

Impact and Significance of Construction Industry

Construction is one of America's most important industries and a critical asset in helping United States industry succeed in a globally competitive market. Today's construction engineers are faced with unprecedented challenges and opportunities in planning, designing, building, and managing public and private facilities to meet the needs of society. The construction industry is everywhere society looks. Modern society relies on the construction industry for producing commercial and industrial facilities for business, civil infrastructure for public and private needs, and housing for residents.

Across the United States, construction is an economic and employment juggernaut, accounting for more than 12% of the nation's gross domestic product, and providing the infrastructure in which we live, work, and play. In economic terms, the value of public construction in 2006 was $269.3 billion, 10% above the $244.7 billion spent in 2005. Educational construction in 2006 was $70.1 billion, 6.5% above the 2005 figure of $65.8 billion and highway construction was $75.1 billion, nearly 15% above the $65.4 billion in 2005. In addition, the value of private construction in 2006 was $928.7 billion, 3.3% above the $899 billion spent in 2005. Residential construction was $630.3 billion, 1.9% below the 2005 figure of $642.3 billion and nonresidential construction was $298.4 billion, 16.2% above the $256.7 billion in 2005 (U.S. Census Bureau 2007, 2006). The construction industry is a large employer as well. The United States Bureau of Labor Statistics reports that slightly less than 10 million Americans are employed in some sector with the construction industry.

As vital as the construction industry is to our nation's stability and economy, it is a difficult entity to grasp. It is fragmented and often inefficient. "Over 44,000 jurisdictions at the state and local government levels regulate building design, construction, and renovation through a confusing, diverse, and, at times, conflicting array of codes, standards, rules, regulations, and procedures. Economies of scale, reduced life cycle costs, enhanced operating efficiencies achieved by other industries such as automobiles and aircraft, through the effective application of information technology to the design, construction, and operation of such products, have not been achieved in the United States construction industry" (Joachim and Wible 2003). If challenges within the industry are not enough, future engineers will likely face breakthrough technologies that will occur with unrelenting speed that threatens to make today's engineering credentials and qualifications antiquated by comparison. According to *The Engineer of 2020*, "The engineering community will face a world which is more connected than today, requiring both social and political acumen to navigate the changing world conditions" (National Acadamy of Engineering 2004). That National Academy of Engineering (NAE) report predicts that the next several decades will offer enhanced opportunities for engineers, with exciting possibilities in the areas of nanotechnology, information technology, bioengineering, and many other specialized fields.

Construction Engineering and Management Education Today

Construction engineering and management (CE&M) education is built upon the fundamentals of civil engineering. Most programs offer students a balance of programs and coursework in construction technologies and management philosophy and practice, with additional study from other disciplines to provide candidates with the skills and experiences needed to successfully negotiate the terrain upon graduation.

As educational programs advanced to meet the needs of a demanding society, so too did the definition of what construction engineering should entail. Here is how the National Science and Technology Council defined construction engineering education in 1994: Construction engineering education focuses on the entire life cycle of a project. This includes initial planning and programming, design, manufacturing, and site construction, occupancy and maintenance, condition assessment, retrofit and renovation, or removal (National Science and Technology Council 1994).

Aligning the educational outcomes of engineers has long been a focus of the professional societies. What ASCE said in 1958 remains true today: "It is imperative that the civil engineering profession begin now to redefine and reorient the educational processes to meet the needs of the present and the challenge of the future. Improvement in the quality of professional education is the essential first step in the enhancement of professional status" (The Cooper Union et al. 1960).

Ensuring that consistent standards are applied in the professional education of construction engineers resides with ABET, Inc. ABET, Inc., is the recognized United States accrediting agency of college and university programs in applied science, engineering, technology, and computing. Accreditation ensures the quality of the postsecondary education that program graduates receive. Just eight programs have achieved ABET, Inc. accreditation for their construction and similarly named engineering programs. The accredited CE&M programs are at the following institutions:

- The American University in Cairo, Cairo, Egypt;
- Iowa State University, Ames, Iowa;
- North Carolina State University at Raleigh, Raleigh, N.C.;
- North Dakota State University, Grand Forks, N.D.;
- Purdue University at West Lafayette, West Lafayette, Ind.;
- University of New Mexico, Albuquerque, N.M.;
- University of Wisconsin–Madison, Madison, Wis.; and
- Western Michigan University, Kalamazoo, Mich.

The following criteria apply to these ABET, Inc. accredited CE&M programs:

Curriculum: The program must demonstrate that the graduates have:

1. Proficiency in mathematics through differential and integral calculus, probability and statistics, general chemistry, and calculus-based physics;
2. Proficiency in engineering design in a construction engineering specialty field;
3. An understanding of legal and professional practice issues related to the construction industry;
4. An understanding of construction processes, communications, methods, materials, systems, equipment, planning, scheduling, safety, cost analysis, and cost control; and
5. An understanding of management topics such as economics, business, accounting, law, statistics, ethics, leadership, decision and optimization methods, process analysis and design, engineering economics, engineering management, safety, and cost engineering.

Faculty: The program must demonstrate that the majority of faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience. The faculty

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must include at least one member who has had full-time experience and decision-making responsibilities in the construction industry (ABET Inc. 2004).

Another organization, the Associated Schools of Construction (ASC), has a long-standing and valuable commitment to improving construction education. ASC includes nearly 100 institutions of higher education, as well as many industrial and governmental members that are jointly dedicated to improving construction education and promoting excellence in curricula, teaching, research, and service to society.

Both organizations—ABET, Inc. and ASC—provide much-needed services in enhancing the effectiveness and delivery of services within the construction industry. Whereas ABET, Inc. is focused on the sciences, engineering, technology, and computing, ASC directs its efforts on education, and analysis of delivery systems, management practices, and construction productivity.

Blueprint for Tomorrow

Pressures facing the world's populations have accelerated in recent years. These include issues such as energy use, sustainable practices, global warming, and environmental pollution. The role of engineers to plan, design, build, and operate systems to serve the public welfare has taken on a new sense of urgency. Engineers must be educated to not only understand, but to balance and apply what they know amidst the complexities of the natural world, the built environment, and the needs of society. The challenge is one of constant innovation and execution: to improve our standards of living, to meet the expectations of clients, to protect natural resources, and to inspire and prepare the next generation of engineers as scientists, sociologists, leaders, and business people.

For future construction engineers to meet the needs of society, educators and those involved in professional practice as mentors and advisors must help prepare the future generation of engineering practitioners by integrating key concepts to enhance critical thinking, understanding globalization, expanding social awareness, and using information technology to enhance learning.

Integrating Key Concepts

To succeed in any endeavor in today's complex, interconnected world, the professional engineer requires essential qualities beyond the assumed technical foundation of an engineer's education. These new qualities include the ability to assume leadership positions, to manage others amid a swirl of cultural dynamics, to articulate ideas, to communicate effectively, to understand and cultivate diversity, to work with and on multidisciplinary teams, and to think critically.

Education and experience that are balanced with an appropriate mix of study in the humanities and social sciences will enable engineers to be more adept at a process of focused, organized evaluation known as critical thinking. Critical thinking is often associated with the steps required to solve complex real-world problems, devising multiple solutions to problems, forming conclusions, synthesizing and integrating relevant information, distinguishing between fact and opinion, and forecasting potential outcomes. These steps clearly align with the six categories of human thinking according to Bloom's Taxonomy (BT) (Bloom et al. 1956). Encouraging students to think at higher levels, beyond simple recall, is a proven way to stimulate students' overall thought processes. According to BT, human thinking can be organized into the following six categories: (1) knowledge; (2) comprehension; (3) application; (4) analysis; (5) synthesis; and (6) evaluation. In reviewing these six levels, higher-level thinking skills occur at the top three levels of BT: analysis, synthesis, and evaluation. Engineers without the ability to analyze, synthesize, and evaluate will likely perform with a narrow project view in which thinking and planning can be misdirected, where information accessed for decision making may be biased or out of context, and where optimum outcomes are never realized. On the other hand, critical thinkers rely on a technical foundation that is strengthened by a balanced base of liberal arts and ongoing experience.

Integrating such critical thinking skills into and across the curriculum is not always easy. It requires constant attention to thinking about how humans think, to thinking and analyzing how and what we teach, and to how students learn. Without such higher-level thinking skills, even the best engineering students will never perform to their maximum potential. If students are to be prepared with the skills, tools, and inquisitiveness needed for life-long learning and for success as future engineers, educators must be prepared to seek solutions and new ideas beyond the narrow focus of specialized fields. For engineers of the future to succeed in service to society, they must be skillful in cooperative problem solving, and be motivated to seek, use, and apply knowledge and information. To do this, they need the assistance and guidance of creative and innovative educators in an environment that fosters higher-level thinking and a strong sense of inquiry and discovery.

Unfortunately, typical knowledge-based instruction fails to integrate key concepts from the humanities and social sciences in the context of the current learning environment, and does not leverage the student's current knowledge base for further development. It has been noted that too much focus has been applied to teaching engineers how to calculate and record, versus how to think, read, and lead.

We have to integrate multiple concepts across the curriculum and fundamentally rethink what and how students are taught and how they learn. Rather than a superficial approach that implies "humanities and social sciences are important," we must highlight where these disciplines surface in the context and discussion of a project's plans.

ASCE articulated a body of knowledge (BOK) required for professional practice, and is developing a second BOK that includes requirements in humanities and the social sciences. In recognizing the need for a second BOK, ASCE has recognized that a broader liberal education will enable engineers to think critically about projects and issues, and develop solutions to problems that are based jointly on math, science, engineering technology, and humanities and the social sciences. It is the writers' belief that our profession is thoroughly capable of teaching and developing in students the skills associated with the technical requirements of the profession. The profession of engineering was founded on technical fundamentals; it will be strengthened by a commitment to professional fundamentals. While technical skills are required, they alone are not sufficient for the individual's success as tomorrow's engineering practitioner and for the overall success and future of the engineering profession. It is the writers' stance that the development of skills and abilities in what we refer to as the professional domain—leadership, communication, diversity, teamwork—carries equal weight in the comprehensive development of a successful engineer and professional.

Another aid in integrating key concepts across the curriculum is to provide students with an opportunity to interact with professionals using real projects as an educational vehicle.

At the University of Wisconsin–Madison, for example, engi-

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neering students benefit from a field observations class where educators take students to job sites, and use that environment as a robust teaching tool. This is an excellent example of content-centered learning, where the content of the actual project facilitates learning and provides the context for real work applications, challenges, and solutions. This is an ideal opportunity for people-centered learning, because students come into contact with many different trades people while on the job site and observe their day-to-day activities. There is nothing like watching an ironworker laying out and tying rebar on a 10°F cold day in Wisconsin to appreciate the work of our construction laborers and to gain a deep-seated respect for labors' contributions to a construction project.

Real-world experiences are critical in the development of the next generation of construction engineers and managers. When CE&M students can see a connection between the classroom, actual construction sites, and their aspirations, they are likely to learn more and are able to better apply what they learn in substantive ways. Community construction companies, industrial partners, and members of a university–industry partnership can be powerful partners as teachers. They spark ideas for innovative curricular change and provide a fresh perspective on what engineers need to know to be successful and productive in their work. In addition, with a new and accurate perspective on the engineers' world of work, college educators can develop a stronger curriculum that relates to real issues in the real world.

Such practice-based learning is not a new idea. What we are saying today is this: with today's advanced technology and rapid pace, we can too easily run the danger of failing to organize the content within the context of the social framework in which our students currently learn and will operate in the future.

Another key to integrating concepts is to become sensitive to the learning styles of individual students. Every professional in the education process—whether professor or practicing engineer—must think about how students learn and how they will structure the learning experience to meet student needs. We know much more today than we did several years ago about how students learn. Some are audible, some are graphical, some are learning challenged, and some learn best by doing. Optimum instructional design mixes the methods used to facilitate the learning styles of every student. While this is true for any discipline, it is particularly evident and required in construction learning.

With a combination of instruction tailored to student needs and a greater emphasis on liberal arts education, the knowledge, skills, and attitudes of tomorrow's engineers should assist them in meeting new challenges. These three qualities—knowledge, skills, and attitude—characterize what tomorrow's engineers must possess, and were articulated by ASCE at its June 2006 Summit on the Future of Civil Engineering:

1. Knowledge—the civil engineer is knowledgeable about technical and professional topics;
2. Skills—the civil engineer has the skills to apply basic engineering tools; to learn about, assess, and master new technology; to communicate with technical and nontechnical audiences; to collaborate on multidisciplinary teams; and to lead; and
3. Attitude—the civil engineer embraces a range of attitudes that supplement knowledge and skills and facilitate effective professional practice (ASCE 2006).

The ASCE Summit noted that civil engineers of 2025 will face a world quite different from that of today. "An ever-increasing global population that continues to shift to urban areas will require widespread adoption of sustainability. Demands for energy, drinking water, clean air, safe waste disposal, and transportation will drive environmental protection and infrastructure development. Society will face increased threats from natural events, accidents, and perhaps other causes such as terrorism" (ASCE 2006).

According to summit attendees, effectively dealing with these issues will require a global commitment by civil engineers to lead more, to collaborate more, and to secure a greater understanding of the human and social implications of projects. The summit report stated that civil engineers possess an impressive legacy, yet an uncertain future. Further it stated that there are acknowledged steps the profession must take: "They know they must take more risks, they know they must show more leadership, and they know they must control their own destiny and not let events control them" (ASCE 2006).

During the summit, attendees drafted the following aspiration statement on the responsibilities that civil engineers have to society:

"Entrusted by society to create a sustainable world and enhance the global quality of life, civil engineers serve competently, collaboratively, and ethically as master:

1. Planners, designers, constructors, and operators of the built environment, which is society's economic and social engine;
2. Stewards of the natural environment and its resources;
3. Innovators and integrators of ideas and technology across the public, private, and academic sectors;
4. Managers of risk and uncertainty caused by natural events, accidents, and other threats; and
5. Leaders in discussions and decisions shaping public environmental and infrastructure policy" (ASCE 2006).

While the current generation of engineers has been well educated, there is a need to continue to stretch the boundaries of typical engineering education to ensure that the engineering solutions created and executed are appropriate and meet society's expectations.

Many institutions of higher education have received the message and are making changes to the curriculum. For example, students majoring in CE&M could benefit from courses such as:

- Expository writing;
- History of cultures/societies;
- Financial accounting;
- Diverse cultures;
- Literature/performing arts;
- Philosophy of human nature;
- Theology; and
- Public speaking.

These courses are in addition to fundamentals of the major such as mechanics of materials, construction planning and scheduling, geotechnical engineering, and many others.

The complexities and challenges of the modern world present us with a significant challenge in how we, as educators, prepare our students for productive lives as engineers. As Leonhard Bernold has written, the danger is that "college education will be replaced by much cheaper Internet-based engineering programs that look a lot like the lecture-oriented teaching of today." The challenge he notes is to empower students to excel in a new educational paradigm. If we do not, the risks are great: "It is imperative that we, as a group, take on this challenge in a scientific manner or we will run the danger of becoming obsolete in due time" (Bernold 2005).

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Understanding Globalization

We frequently and mistakenly believe that globalization is something new. It is not, but it is true that only recently have our abilities to annihilate geography been greatly enhanced through advanced technologies.

People have always been trying to connect with one another over long distances to advance commerce, conquer new lands, and explore new territory. In 1848, the socialist theorist Karl Marx described a fascinating notion of what was then known as territorial compression. According to Marx, the needs of capitalist production forced the bourgeoisie to "nestle everywhere, settle everywhere, and establish connections everywhere" (Tucker 1972).

Observations on the increasing connectedness among people were not the sole domain of European intellectuals. John Dewey, a Columbia University psychologist, philosopher, and author, wrote in 1927 that economic and technological trends created a new world no less significant than the discovery and expansion of the North American continent. From Dewey's perspective, the invention of steam, electricity, and the telephone offered new ways of travel, manufacturing, and communications—innovations that provided challenges to the typical definition and boundaries of community life that had long been the norm (Dewey 1927).

The inventions and innovations have never stopped. The transportation and communication revolutions have shrunk the planet and swept away the geographical barriers that had long separated human endeavor into regions of cultural activity and tradition. Technologies have increased the possibilities for human interaction across borders and thus the integration of markets, nation states, technologies, and skills to a degree we have never seen before. In the words of one observer, "the globalization that we are experiencing today is unprecedented in its magnitude and reach" (Bugliarello 2005). Globalization has created worldwide opportunities for many countries, and the debate continues regarding the long-term effects on the economies of the United States and other countries. As Bugliarello has noted, "globalization can weaken us, or it can offer us, and the world, hope that we can find ways to avoid global conflicts and improve human welfare. But we must act now to ensure that the United States continues to prosper and has the strength and talent to contribute to improvements in the security and quality of life for people everywhere" (Bugliarello 2005).

For many industries, the decision to establish a global presence has been made for them by changes taking place in the business world around them. The construction industry is no exception. As vital as CE&M is to the American economy and landscape, its scope has become global. As an example, construction giant Bechtel is completing projects in many countries, from an aluminum smelter in Iceland, to port and industrial zone development in the United Arab Emirates. As a further example, consider construction tower cranes, which for years have dominated the construction scene in Europe. These tower cranes are now increasingly used in North America. Potain of France, the world's leading manufacturer of tower cranes, is now owned and operated by Manitowoc Crane Group of Wisconsin, traditionally a major manufacturer of crawler cranes. From another industrial perspective, and as a final example, global pharmaceutical companies have increased manufacturing capacities around the world and particularly in Asia.

America has long enjoyed an innovative, technological leadership position among the world's countries. In recent years, however, we have witnessed the locus of economic growth shift to countries such as South Korea, India, and China. These countries are intently focused on developing their own financial markets, pursuing leading-edge technology, and increasing international trade.

China, for example, has opened its economy to foreign investments and domestic entrepreneurs, and has become one of the world's foremost exporters and a leading consumer of oil and other natural resources. Asia is the world's biggest construction market, and China makes up the bulk of construction projects, reports the United States Commercial Service (USCS), the trade promotion division of the International Trade Administration within the United States Department of Commerce (U.S. Department of Commerce 2007). USCS notes that China's construction industry has sustained consistent growth in recent years, with a particular focus on roads, rail systems, bridges, ports, and airports. The country's real estate market has been booming, powered by China's housing reform program and rising personal incomes. Many observers are already predicting that before the end of the 21st century, China will surpass the United States as the planet's chief economic power. What all this means to CE&M is this: huge opportunities in building and construction. Billions of dollars are being invested in Asia and many other areas worldwide in land development, and the building of housing, power plants, manufacturing facilities, the infrastructure for increased transportation needs, and telecommunications systems.

What does globalization mean to CE&M? Two thoughts for consideration:

1. We are still early in the process of understanding globalization and its effects on our professions and lives; and
2. The marketplace is full of global opportunities. In response, we must be prepared to act on those opportunities.

Expanding Social Awareness

Construction projects of any scale carry social implications. Implications of highway construction, for example, may revolve around issues of traffic safety, neighborhood impacts, and acquisition of land. Large-scale industrial construction projects possess their own social implications that may include urban design and public transit, environmental impacts, and how a project fits into the fabric of community. Furthermore, social issues are paramount in developing countries where the fabric of daily living can be affected by large-scale industrial and infrastructure projects. Such implications include issues such as property ownership, transportation, traditional modes of commerce, concerns for the environment, unintended consequences, and potential conflicts of interest. Even in fully developed areas, social and ethical issues of construction projects require careful consideration and an understanding of the role of multiple stakeholders.

Future engineers need a comprehensive understanding of the social implications of projects. Many observers believe that engineers tend to focus on the bricks and mortar and the technology rather than the social context in which engineering solutions are created and applied. In short, engineers must further refine and develop their abilities to see and understand the integral factors that characterize the environment where science and society come together.

The engineering solutions of tomorrow will require heightened collaboration among the technical disciplines, probably more so than ever before. This will be especially true where systemwide solutions will be required in high-density urban settings to deal

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with issues such as air and water quality, environmental conditions, waste management, traffic congestion, and overall quality of life.

As engineers and builders, we occupy a position with a truly unique opportunity: to participate in the dialogue in making the world a better place; to help protect the globe's ecosystems; and to help solve some of the world's biggest challenges, from waste management, to global warming, to energy and urban land use.

For today and tomorrow's construction engineers, it is a world of challenge and opportunity. The challenge is not only to build new structures and to improve quality of life, but to also maintain what we have, and, if opportunity can be described as formidable, this is certainly an appropriate characterization. According to ASCE's *2005 Report Card for America's Infrastructure*, the country's infrastructure is crumbling. The report assigns a cumulative grade of D for the nation's roads, bridges, drinking water systems, and other public works. These systems, ASCE says, have shown little to no improvement since they were graded an overall D+ in 2001, with some areas sliding toward failing grades (ASCE 2005). Two examples are as follows:

1. America's commitment to quality drinking water graded the lowest at D–. ASCE reported that the country faces a shortfall of $11 billion annually to replace aging facilities and comply with safe drinking water regulations. Federal funding for drinking water in 2005 remained level at $850 million, less than 10% of the total national requirement; and
2. America's 590,750 bridges were graded C. ASCE reports that it will cost $9.4 billion a year for 20 years to eliminate all bridge deficiencies, and that more than a quarter of the nation's bridges are structurally deficient or functionally obsolete.

Let there be no question about the social relevance of a deteriorating infrastructure. Such systems—from water supplies to waste disposal and public transportation—form the foundation of quality, contemporary living; they are the construction/engineering determinants of a good life. The implications for such effects are significant for those involved in urban policy and social planning, and for people who live in these environments. The concerns over the social impacts of crumbling infrastructure are pervasive, intense, and enduring.

Challenges beyond United States borders become even more formidable as the world becomes increasingly crowded and polluted. The planet is well on its way to a population of more than 10 billion people, and according to ASCE'S vision for 2025, "they are straining the earth's environment, particularly the needs for energy, fresh water, clean air, and safe waste disposal" (ASCE 2006).

David C. Korton, in *The Great Turning*, described the challenge like this: "The human species is entering a period of dramatic and potentially devastating change as the result of forces of our own creation that are now largely beyond our control. It is within our means, however, to shape a positive outcome if we choose to embrace the resulting crisis as an opportunity to lift ourselves to a new level of species maturity and potential" (Korten 2006). Engineers have a tremendous opportunity and responsibility to participate in the dialogue and solutions for a better world.

At the beginning of this paper the writers described a parallel between the growth of engineering and the growth of our country. A similar comparison applies today, with a focus much more urgent. The issues that confront the world today are the same issues that challenge engineers. To meet the challenge, the profession of engineering needs to grow again, to meet the demands brought about by issues such as resource use, energy, population, terrorism, environmental pollution, and many more.

We have made the transformation from an industrial to a knowledge-based society. Furthermore, college education itself is not what it used to be. Today, more than 75% of high school graduates pursue some level of postsecondary education within 2 years of receiving their high school diplomas. "A college degree has in many ways become what a high school diploma became 100 years ago—the path to a successful career and to knowledgeable citizenship" (Association of American Colleges and Universities 2002).

Using Information Technology to Enhance Learning

If you have ever observed a college student on the social networking Web site *Facebook*, you know how engrossed they can be with the technology and what unfolds on the monitor before them. They are thrilled, totally mesmerized by the tools and technology before them. In some cases, technology can become intoxicating, and habitual users, such as the college student noted above, can find his or her studies taking a back seat to social networking. We need to ensure that engineers do not react in such a manner that the magnetism of information technology (IT) obscures their abilities to assess project implications beyond the technical realm.

To capitalize on the potential of IT as a means of reaching and teaching the next generation of construction engineers and mangers, it is important to recognize that IT can be viewed as contributing to three separate desired educational outcomes:

1. Communication and teamwork: Increasingly, computers have become a cornerstone to quality communication, teamwork, and construction. The Internet and the various communications tools that have been spawned by the Internet, such as instant messaging, voice over Internet protocol (VoIP), video conferencing, data mining, searching, browsing, video gaming, pod casting, and massively multiplayer online games (MMOGs), are second nature to most of our students. Technologies model how people can best collaborate on projects, and computer programs can visualize the various stages of a construction project over time using three-dimensional models. Such visual construction planning tools help bring managers and field personnel closer together, thus producing huge gains in communication, scheduling, and collaborative problem solving.

   The lines between entertainment and learning have been blurred to a large extent by the use of these tools. We can, and should, take advantage of this reality. Doing so allows us to reach students in many different ways and to communicate with them interactively—both synchronously and asynchronously. IT communication technologies such as Skype, VSee, NetMeeting, Instant Messaging, Interactive Forums, and collaborative project posting and reviewing (on course homepages) in undergraduate and graduate courses add to the immediacy of the information being exchanged and serve to excite the students. This leads to better teamwork through constant feedback and communication, and breaking down power structures and social barriers between the students themselves and between the students and the instructors.
2. Proficiency with state-of-the-practice computer software: In engineering education, IT is often confused with computer technology—the specific computer programs that we use to perform engineering analysis and design. Knowing how to use TIMBERLINE, PRIMAVERA, and AUTOCAD (or their

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equivalents), for example, is nowadays a necessary part of engineering technological education but, we contend, not a sufficient part. The sufficiency is the synergism that is created by use of these tools and the thinking that develops when such tools are combined with the communication tools described above, especially in cyberspace. Software technologies are continually changing the way engineers plan, analyze, design, and communicate. Students are much more aware these days of the most current and sophisticated subject-specific software tools that are being used in the industry. Therefore, we need to ensure that our students have access to and familiarity with these leading edge software tools throughout their education in their specific discipline. Along with this, it is becoming increasingly important to emphasize to students the need to understand the hazards of using sophisticated software tools and to teach them to be able to evaluate whether their computer model predictions are reasonable and applicable to the real world.

3. Creating a technologically and globally literate community. IT and the Internet will help us develop the "educated citizen" that we need to lead the construction industry of the future. Students need to understand how to mine the Internet and to use it for inspiration and resources in an intelligent and focused manner. This requires developing a global view of history and geography as well as of cultures and societies. As noted above, our computer technology ties us to the visual and audible, but yet we are most often dependent on the written word to truly understand content, and this requires reading and writing. Engineering students must come to understand the value of reading and writing and of thinking very deliberately about technical and nontechnical material. With Internet resources, they have access to unlimited reading material—but often they seem confused as to how to really read the material and assess its relevance.

Students are wired constantly and they expect nothing less from those with whom they come in contact. The degree of connectedness between learner and educator is much different today from just 5 years ago. Educators and students used to define teaching and learning as going to class, listening to a lecture, taking notes, giving homework, and entertaining questions from students during office hours. Office hours are such an antiquated notion. Today, office hours are constant, with access via e-mail and other forms of text- or voice-based communications. The rate of which knowledge is created, absorbed, and communicated is much different today, and we need to adapt to the methods that students are using out there on the leading edge.

Students have an incredible range of opportunities before them—career paths, potential jobs—the writers' point is that for CE&M to be viable as a profession, we must structure it to attract, retain, and develop young people. Making full use of IT in CE&M education is paramount. As Li has noted, "The role of information technology in assisting constructive learning is to provide a source of information that can be accessed by students in a manner uninhibited by time and location" (Li 1998).

Higher education has gotten the message. Colleges and universities are striving to integrate new media and new technologies to improve student learning. "Information technology is more or less the paper and pencil of the 21st century," is the analogy used by Charles M. Vest. For engineering students, he noted, information technology is like the air they breathe, "simply there to be used, a means, not an end" (Vest 2006). Such technology can be a great enabler of learning and may include everything from e-books that can be loaded to a personal digital assistant (PDA), to online courses, e-mail between instructor and students at any time, and simulation technology.

Fully grasping the promise and potential of technology-aided learning is an ongoing challenge. What was leading edge today is antiquated tomorrow. A proven method to advance learning through technology is to experience the technology, talk to colleagues at other institutions, and discuss one's objectives with potential vendors or one's own information systems staff.

Summary

Planning for the future is a continuous process. It requires the ongoing evaluation of our work, the continued sharing of experiences, a commitment to developing a global perspective and leadership qualities of professional engineers, and the carefully considered adaptation of new insights and evolving technologies. The future is a grand, compelling set of circumstances that rolls along on the horizon, just out of reach. Even though the future is beyond our immediate reach, we can perceive what is coming and we should be concerned. The great task for us, and for those who come after us in the profession of engineering, is to see that the engineer of tomorrow shall have a quality, a character, and a presence worthy of the opportunity. The engineering profession has a proud, productive history. Then, as now, the future challenges us to make all things possible.

The successful construction engineer will be fully vested in practice, profession, and social responsibility. Former United States suffragist and social reformer Elizabeth Cady Stanton, in an 1892 speech before a United States Senate committee that was considering arguments in favor of women's suffrage said, "Nothing strengthens the judgment and quickens the conscience like individual responsibility" (Stanton 1892).

Civil engineers, perhaps more than any other professional practitioner, carry profound individual responsibilities for designing and building the systems that affect how people live. It is not always easy. Engineers can expect social and ethically complex situations to arise as part of their everyday modern practice. Resolving these issues will require patience, understanding, and equal measures of analysis and synthesis. Engineers possess the supreme challenge of building a better tomorrow. As educators, mentors, and advisors, we have the supreme challenge of helping get them ready.

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