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Consultant

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He has served on and chaired various committees and other groups. For example, he was Chair of the ASCE Urban Water Resources Research Council, a member of the ASCE Task Committee on the First Professional Degree, and served on the Indiana Board of Registration for Professional Engineers. Most recently he was editor of the 2008 report Civil Engineering Body of Knowledge for the 21st Century.

In 1995, Walesh received the Public Service Award from the Consulting Engineers of Indiana; in 1998, the Distinguished Service Citation from the College of Engineering at the University of Wisconsin; in 2003, the Excellence in Civil Engineering Education Leadership Award presented by the ASCE Educational Activities Committee; in 2004, he was elected an Honorary Member of ASCE; in 2005, he was elected a Diplomate of the American Academy of Water Resources Engineers; and in 2007, he was named Engineer of the Year by the Indiana Society of Professional Engineers and received a Distinguished Service Award from the National Society of Professional Engineers.

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Fork in the Road: Choosing a Bright Future for Engineering

Abstract
Improvements to, and in some cases reformation of, U.S. engineering education have been studied and discussed for decades. While progress occurred, it has fallen short of reform. However, the profession recently reached a tipping point in that some elements of the engineering profession have seen a definitive fork in the road and are going in a new direction, they have seen “two roads diverged” and are taking the “one less traveled.”

This presentation reviews some of the forces driving reform with special mention of the stewardship factor. Then the presentation demonstrates that significant elements of U.S. engineering are heading in a new direction regarding the formal education and early experience of engineers. Specific reform actions and their significance are noted. Finally, the presentation encourages current non-participants, whether they be individuals or organizations, to proactively participate and suggests how.
**INTRODUCTION**

The first of the three purposes of this paper is to briefly cite forces driving reform of the education and early experience of engineers. This first purpose is treated in cursory fashion, with the exception of one of the driving forces. The second purpose is to demonstrate that significant segments of the U.S. engineering community are heading in a new direction regarding the formal education and early experience of engineers. And “heading in a new direction” means having gone well beyond discussion and planning—it means doing. The third and last purpose of this paper is to encourage current non-participants, whether they are individuals or organizations, to proactively participate and suggests ways to do so.

**FORCES DRIVING REFORM**

As noted, the first purpose of this article is to briefly review arguments for reforming the formal education and early experience of U.S. engineers. Those arguments have been convincingly made by many with increasing frequency, over the last decade or so. For example, see reports and other documents produced by various engineering organizations such as the American Academy of Environmental Engineers (AAEE),\(^1\) the American Society of Civil Engineers (ASCE),\(^2,3,4\) The National Academy of Engineering (NAE),\(^5,6,7\) the National Council of Examiners for Engineering and Surveying (NCEES),\(^8\) the National Society of Professional Engineers (NSPE),\(^9\) and the University of Michigan.\(^10\)

**Visionaries and Their Influence in Driving Reform**

Allow me a personal reflection. For over 30 years, beginning with Samuel Florman’s book, *The Existential Pleasure of Engineering*\(^11\) and later *The Civilized Engineer*\(^12\) and *The Introspective Engineer*\(^13\) and his many articles, I have enjoyed, been enlightened by, and most significantly, been inspired by his repeated, thoughtful calls for major improvements in our profession.

During that time, reform messages were also offered by other academic and practitioner visionaries including L. L. Guy,\(^14\) R. K. Kersten,\(^15\) L. G. Lewis, Jr.,\(^16\) D. H. Pletta,\(^17\) J. M.
Roesset, J. P. T. Yao. Through their forward looking writing and speaking, they urged engineers to extend and broaden their formal education, attract the “best and brightest” young people, enhance their value, seek leadership positions in government, expand mandated licensure, and influence public policy. Seeds planted by all of these individual and organizational calls for reform have borne fruit, reform has started, and is growing.

Table 1 summarizes forces driving the education and early experience of engineers. With one exception, this paper does not dwell on these forces given that, as already indicated, they have been deeply and broadly discussed elsewhere. Stewardship is the exception.

**Poor Stewardship**

As a former engineering faculty member, dean, and supervisor of young engineers in the public and private sectors, I know that incoming engineering students have traditionally been among the brightest and most accomplished of all students entering our universities and those strengths carry over into their engineer intern experience. Engineering as a whole risks losing this edge, that is, continuing to attract the best and brightest. Why? Because of our under-utilization of talent.

We—educators and practitioners—owe aspiring engineers a deeper and broader education and early work experience so that they can more fully develop and use their special gifts. Education and early experience have expanded the left sides of their brains while not giving enough attention to the right sides. Perhaps our educational programs, in terms of how engineers view themselves, have tended to train technicians rather than educate professionals.

As a result of my work as an employer and as an independent consultant, I have seen too many bright, young people functioning in narrow, technical roles while not realizing—or being encouraged to realize—the success and significance they could achieve. I’ve observed young professionals, and some not so young, spending too much of their time doing work that they should delegate to clerical personnel, technicians, and technologists so that they could perform higher valued functions. Engineering, at least civil engineering, in contrast with other professions such as medicine and law, makes poor use of paraprofessionals.
Table 1. Forces Driving Reform of the Education and Early Experience of Engineers

<table>
<thead>
<tr>
<th>Issue/problem</th>
<th>Representative source*</th>
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</thead>
<tbody>
<tr>
<td>Gradual reduction in credit hours, including engineering-related content,</td>
<td>ASCE, 3</td>
</tr>
<tr>
<td>required for the bachelor’s degree</td>
<td>Russell et al., 19</td>
</tr>
<tr>
<td>Curriculum stagnation</td>
<td>Armstrong, 20</td>
</tr>
<tr>
<td>Slippage in length of formal education relative to other professions</td>
<td>ASCE, 3</td>
</tr>
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<td></td>
<td>Smerdon and Russell, 21</td>
</tr>
<tr>
<td>Explosion of technology</td>
<td>NAE, 5</td>
</tr>
<tr>
<td>Non-engineers increasingly managing engineers</td>
<td>ASCE, 3</td>
</tr>
<tr>
<td>Globalization and its demographic, cultural, economic, health, environmental,</td>
<td>NAE, 5</td>
</tr>
<tr>
<td>infrastructure, and security challenges</td>
<td>NAE – NAS – IM, 7</td>
</tr>
<tr>
<td>Need for attributes such as “strong analytical skills, creativity, ingenuity,</td>
<td>NAE, 5</td>
</tr>
<tr>
<td>professionalism, and leadership.”</td>
<td></td>
</tr>
<tr>
<td>Gross under-representation of women in engineering</td>
<td>Loftus, 22</td>
</tr>
<tr>
<td></td>
<td>National Council for Research on Women, 23</td>
</tr>
<tr>
<td>Poor stewardship with the talented youth that have traditionally entered the</td>
<td>“Poor Stewardship” section of this paper</td>
</tr>
<tr>
<td>study of engineering</td>
<td></td>
</tr>
</tbody>
</table>

*Sources are intended to be representative, that is, not all inclusive. Numbers refer to the Notes and Cited Sources at the end of this paper.
Too few engineers become actively involved in professional and business societies and community activities, including running for public office. Young engineers have the intellect and work ethic needed to be successful in these professional and public roles. However, they don’t know what they don’t know. They don’t know what they could be within and outside of their employment. The die was cast in college and is reinforced in early employment. Poor stewardship on our part.

The good news is that the reform which is now underway in segments of our profession addresses the stewardship issue. NAE defines attributes of 2020 engineers. Besides the traditional and essential strong analytic and communication abilities, additional needed attributes include: practical ingenuity, creativity, business and management fundamentals, leadership ability, agility, resilience, and lifelong learning.

As a concrete example of what is being done to provide these new broader attributes, consider the 24 outcomes within the Civil Engineering Body of Knowledge (BOK). In addition to maintaining or strengthening mathematics, natural sciences, and engineering sciences, and achieving greater technical depth, the BOK explicitly and clearly calls for broader exposure to the humanities and social sciences and additional professional practice breadth. To emphasize, these broader knowledge, skills, and attitudes are clearly defined. Furthermore, some of these outcomes have already been reflected in accreditation criteria. More importantly, some engineering programs are implementing the broader and deeper BOK based on its merits. Finally, other disciplines are considering implementing similar breadth expectations needed by the 21st Century engineer.

Most engineering students and engineer interns respond to what is expected and supported. We have, by virtue of traditional engineering education and the way we manage early experience, expected too little, practiced poor stewardship. The reform effort now underway in portions of our profession is solving this problem by expecting and supporting much more, that is, by raising that bar both during formal education and early experience.

A NEW ROAD FOR SOME SEGMENTS OF ENGINEERING

So much for forces fueling reform. The second purpose of this paper is do demonstrate that critical segments of the U.S. engineering community are taking a new route in the formal education and early experience of engineers.

The Fork In The Road

According to Yogi Berra, “When you come to a fork in the road, take it.” Robert Frost, using more elegant prose, offered similar advice when he wrote “Two roads diverged in wood,… I took the one less traveled by, and that has made all the difference.” Some elements of our profession have come to that fork and have taken it by beginning to reform—not just discussing reform or planning reform—the education and early experience of engineers. They have approached the divergence, taken the road less traveled, or more precisely, not yet traveled and see that the chosen path promises to make “all the difference.”
Other elements of the engineering community are approaching the fork, that is, the diverging roads. They have the opportunity to take it; to travel on the road less traveled, the one that will make “all the difference.” I hope that many do in the spirit of determining their future, rather than having others do it for them. American statesman William Jennings Bryan reminded us of the power of choice when he said “Destiny is not a matter of chance, it is a matter of choice.” While examining and striving to improve the entire career of engineers is desirable, clearly how we prepare and orient new members of the profession has highest priority. The reform effort begins at the beginning, as it should.

Reform Actions

Table 2 summarizes definitive and strong reform actions taken by various U.S. engineering societies over the past decade. Some of these actions have, in turn, already caused changes, or will cause changes, in the education and early experience of engineers. As noted, the table includes strong definitive actions that already have or will lead to reform. Nothing listed in the table can be categorized as recommending “more of the same” or of just fine-tuning, refining, or “tweaking” the current approach. Presented below are thoughts to supplement information in Table 2.

ASCE – 1998 to the Present

Reformation of U.S. engineering education has been studied and discussed for decades. Seeley, to use his words, identifies “the main currents in various reform movements.” He describes the gradual evolution of engineering education beginning with adoption of the Morrill Act after the Civil War which established land grant schools that shifted the dominant pattern of “engineering education from shop floors to classrooms.” He cites key studies including the 1927 Wickenden report which recommended less hands-on specialization and more attention to mathematics and science. The 1956 Grinter report stressed the value of engineering science and led to much more fundamental research. The controversial 1966 Walker report, according to Seeley, “proposed addressing overloaded curricula by instituting a generalized undergraduate degree and reserving specialization for the master’s level.”

While improvements have occurred in engineering education, they have been evolutionary, not revolutionary. These improvements fall short of reform. For example, at the end of his essay, Seeley offers this summary statement:

\[
\text{Despite these changes, however, many of the challenges facing engineering educators have remained remarkably consistent over time. The question of what to include in tight curricula, how long engineering education should last, how much specialization there should be at the undergraduate level, how to prepare students for careers that include both technical and managerial tracks, and how to meet the needs and expectations of society all seem timeless.}
\]
Table 2. Recent Milestones in the Reforming the Education and Early Experience of Engineers

<table>
<thead>
<tr>
<th>Entity</th>
<th>Date</th>
<th>Action</th>
<th>Significance</th>
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<tbody>
<tr>
<td>ASCE</td>
<td>October, 1998 (Refined in 10/01, 10/04, and 4/07)</td>
<td>Adopted a policy statement which, in its current, refined version, “supports the attainment of the Body of Knowledge (BOK) for entry into the practice of civil engineering at the professional level.”</td>
<td>This is the first time that a U.S. based, discipline-specific engineering society has formally, and at the highest level, called for major reform of engineering education—including adding education beyond the bachelor’s degree—and prelicensure experience.</td>
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<tr>
<td>NSPE</td>
<td>2002</td>
<td>Adopted a professional policy which “supports the concept of engineering students meeting additional academic requirements as a prerequisite for licensure and practice of engineering at the professional level. Possible additional requirements could include a master’s degree or equivalent.”</td>
<td>This is the first time in that a pan-engineering society has called for formal education beyond the bachelor’s degree.</td>
</tr>
<tr>
<td>ASCE</td>
<td>January, 2004 (Second edition published in January, 2008)</td>
<td>Published <em>Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future.</em> Defines, using Bloom’s Taxonomy, the knowledge, skills, and attitudes required of an individual entering the practice of civil engineering at the professional level (licensure) in the 21st Century.</td>
<td>The BOK has proven to be a productive forum for educators and practitioners. Examples of results to date include use of the BOK for program improvement at various universities, revision in accreditation criteria, and modification of the NCEES Model Law.</td>
</tr>
<tr>
<td>NAE</td>
<td>2004</td>
<td>Published <em>The Engineer of 2020</em> which concluded “…if the engineering profession is to take the initiative in defining its own future, it must (1) agree on an exciting vision for its future; (2) transform engineering education to help achieve the vision…”</td>
<td>Ominously suggests that engineering is not now determining its future and points to transforming engineering education (not just refining, fine-tuning) as an essential action. Leads to the upbeat, proactive 2005 NAE report listed next in this table.</td>
</tr>
<tr>
<td>Organization</td>
<td>Year</td>
<td>Event Description</td>
<td>Notes</td>
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<td>NAE</td>
<td>2005</td>
<td>Published <em>Educating the Engineer of 2020</em> which stated, “The B.S. degree should be considered as a pre-engineering or ‘engineer-in-training’ degree. Engineering programs should be accredited at both the B.S. and M.S. levels so that the M.S. degree can be recognized as the engineering professional degree.”</td>
<td>The first time that a U.S. based, pan-engineering society called for dual level accreditation and recommended the M.S. as the engineering professional degree.</td>
</tr>
<tr>
<td>NCEES</td>
<td>September, 2006 (Confirmed in August, 2007)</td>
<td>Approved modification to the licensure Model Law to require that an engineer intern with a bachelor’s degree must have “…an additional 30 [semester] credits of acceptable upper-level undergraduate or graduate-level course work to be admitted to the PE examination.”</td>
<td>Effective in 2015, U.S. licensing jurisdictions that adopt this provision of the Model Law will require a master’s degree or equivalent.</td>
</tr>
<tr>
<td>ABET, Inc.</td>
<td>2007</td>
<td>Approved changes to the Program Criteria for Civil and Similarly Named Engineering Programs (civil engineering program criteria) and approved changes to General Criteria for Masters Level Programs (master’s level criteria),</td>
<td>These changes in accreditation criteria, which will be applied for the first time during the 2008-2009 accreditation cycle, support the reform of civil engineering education.</td>
</tr>
</tbody>
</table>
And, for about two centuries, engineering has, with very few exceptions, adhered to four-year undergraduate education. This four-year degree has continued to be recognized as the engineering professional degree in spite of decades of scientific and technological advances, increased environmental concern, growing threats of disasters, and rapid globalization.

The ASCE Board of Direction’s adoption, refinement, and confirmation of Policy Statement 465 which “supports the attainment of the Body of Knowledge (BOK) for entry into the practice of civil engineering at the professional level” has, in my view, already proven to be revolutionary, to have started reform. This is due, in part, to its uniqueness in that this is the first time a U.S. based, discipline-specific engineering society has, at the highest level, formally called for major reform of engineering education—including adding education beyond the bachelor’s degree—and reform of prelicensure experience.

Table 2 indicates that ASCE published the original and second edition of Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future. The second edition uses Bloom’s Taxonomy, which is widely known and understood within the education community, to describe the minimum cognitive levels of achievement for each of the 24 outcomes (see Appendix A). The outcomes, which are organized into three categories—foundational, technical, and professional—define knowledge, skills, and attitudes that are to be fulfilled by an individual prior to entering the practice of civil engineering at the professional level, that is, licensure. All 24 outcomes are fulfilled or partially fulfilled through the bachelor’s degree. Three outcomes are partially fulfilled by a master’s degree or equivalent and 15 outcomes, almost two-thirds, require experience as an engineer intern for complete fulfillment.

The preceding, relative to today’s approach, and in keeping with Florman’s and others calls for reform, mean that tomorrow’s civil engineer will:

- master more mathematics, natural sciences, and engineering science fundamentals;
- maintain technical breadth;
- acquire broader exposure to the humanities and social sciences;
- gain additional professional practice breadth; and
- achieve greater technical depth—that is, specialization.

Notice how the outcomes provide specific answers, at least for civil engineering, to the questions asked by Seeley in his article. More specifically, the BOK indicates the minimum content in terms of knowledge, skills, and attitudes to be included in curricula (and in experience) and addresses how long formal engineering education should last (bachelor’s degree plus a master’s degree or approximately 30 semester credits of acceptable graduate-level or upper-level undergraduate courses). The BOK also answers the specialization question (it should occur within the master’s degree or equivalent) and how to prepare young people for careers that include both technical and managerial tracks (achieve greater technical depth while acquiring additional professional practice breadth). And finally, the BOK indicates that meeting the needs
and expectations of society will be accomplished by the preceding plus broader exposure to the humanities and social sciences.

Because the BOK focuses on well-defined results—the outcomes—and does not prescribe the means to achieve them,29 and because the BOK calls for “raising the bar,” the BOK has already proven to be a productive forum for educators and practitioners and has produced concrete results within and outside of the civil engineering discipline. For example, the BOK:

- Has been used to modify the ABET Program Criteria for Civil and Similarly Named Engineering Programs (civil engineering program criteria) and the ABET General Criteria for Masters Level Programs (master’s level criteria) and will continue to be used to improve at least the former.

- Is being used to design and/or revise engineering curricula at highly varied institutions. Some example universities, and this is just the tip of the iceberg, are the University of Alabama,33 The Citadel,34 University of Illinois,35 Lawrence Institute of Technology,36 Rose-Hulman Institute of Technology,37 the University of Texas at Tyler,38 and the University of Utah.39

- Has influenced the modification of the National Council of Examiners for Engineering and Surveying (NCEES) Model Law to require formal education beyond the bachelor’s degree.8

- Has prompted elevated discussion of and work on the responsibility of practitioners to coach and mentor young engineers.40 This is one result of the BOK indicating that experience is needed to complete fulfillment of about two thirds of the civil engineering outcomes.

While not necessarily related to the ASCE BOK effort, other engineering disciplines have initiated BOK or similar reform projects. For example, in November 2005, the American Academy of Environmental Engineers (AAEE) Board of Trustees created the Body of Knowledge Development Working Group (BOKDWG) and charged it with “defining the BOK needed to enter the practice of environmental engineering at the professional level (licensure) in the 21st Century…”1 The chemical engineering profession driven in part by the recognition that, over the past 40 years, “the undergraduate curriculum in chemical engineering has remained nearly unchanged,” conducted three workshops in 2003 that produced a vision and model for reform of undergraduate chemical engineering education.20 The American Society of Mechanical Engineers (ASME) will conduct a Global Summit on the Future of Mechanical Engineering on April 16 to April 18, 2008.41 The purpose: “Articulate a global vision for the future of Mechanical Engineering.” Perhaps that conference will lead to reform in the preparation of tomorrow’s mechanical engineers.

NAE – 2004 and 2005
The NAE 2020 project was motivated by the need to better prepare engineers to address issues such as globalization, the connection between education and practice, formulating solutions to increasingly complex problems, and appreciating the socio-political implications of their work.\textsuperscript{5,6,21} The first of the two reports, \textit{The Engineer of 2020},\textsuperscript{5} published in 2004, ominously suggests that engineering is not now determining its future and points to transforming engineering education as an essential action.

The second of the two reports, \textit{Educating the Engineer of 2020},\textsuperscript{6} published in 2005, states “The B.S. degree should be considered as a pre-engineering or ‘engineer-in-training’ degree. Engineering programs should be accredited at both the B.S. and M.S. levels so that the M.S. degree can be recognized as the engineering professional degree.” This NAE action is the first time that a U.S. based, pan-engineering society called for dual level accreditation and the M.S. as the engineering professional degree. The second report also issued this strong call for reform in the preparation of tomorrow’s engineers:

\begin{quote}
The exploding body of science and engineering knowledge cannot be accommodated within the context of the traditional four-year baccalaureate degree. Technical excellence is “the” essential attribute of engineering graduates, but those graduates should also possess team, communication, ethical reasoning, and societal and global contextual analysis skills as well as understand work strategies. Neglecting development in these arenas and learning disciplinary technical subjects to the exclusion of a selection of humanities, economics, political science, language and/or interdisciplinary technical subjects is not in the best interest of producing engineers able to communicate with the public, able to engage in a global engineering marketplace or [educated] to be life long learners.
\end{quote}

\textbf{NCEES – 2006 and 2007}

As noted in Table 2, the NCEES approved modifications of the licensure Model Law to require an intern with a bachelor’s degree to have “…an additional 30 [semester] credits of acceptable upper-level undergraduate or graduate-level course work from approved course providers” or a master’s degree to be admitted to the PE examination.\textsuperscript{8} U.S. licensing jurisdictions\textsuperscript{30} that adopt this Model Law provision will, in effect, be requiring a master’s degree or equivalent. A few licensing boards are already considering the Model Law’s additional education requirement. For example, early this year, a bill was introduced into the Nebraska legislature that would require the 30 credits or a master’s degree to be admitted to the PE examination.\textsuperscript{31}

W. Gene Corley, NCEES president, notes that this new educational requirement will help protect the public. It is part of the progressive increase in standards envisioned 75 years ago by them NCEES president and future NSPE founder David Steinman. Corley states that “Reviewing educational requirements remains an ongoing task in the 21st Century—one that NCEES has undertaken as part of its continuing efforts to assist U.S. licensing boards in protecting public
health, safety, and welfare.” Given scientific and technological advances, increased concern with the natural environment, and threats of terrorism and natural disasters, how could we not at least occasionally raise the educational and licensure bars?
The Rest of the Story

The preceding summarizes the definitive, strong reform actions of several prominent U.S. engineering societies during the past decade. Clearly, engineering has come to a fork in the road and some segments of the profession are taking a new path. The facts indicate that the profession has experienced a tipping point.

A more subtle, but equally important tipping point is the emergence of a growing cadre of reformers. Major change and reform typically begin with the efforts of a core group who envision a much better future, commit to making it happen, conceptualize an implementation plan, and invite others to join the effort. The compelling vision and plan to achieve it attracts others. Already hundreds of engineers, drawn from various disciplines and from the public, private, and academic sectors have actively participated in the reform effort. Those members of various engineering societies have served on or chaired various committees, subcommittees, and task forces; spoken to hundreds of audiences; written papers, articles, and reports; and initiated improvements within their organizations. This cadre of committed individuals assures the continued success of the reform effort, at least within portions of the engineering community.

But, If We Build It, Will They Come?

Having observed, over the years, an array of responses to calls for reform of the engineering profession, I’ve noticed that even receptive academics and practitioners often respond with cautious, if not fearful, “but” statements. For example: “But if our engineering discipline raises the bar, won’t students migrate to other engineering disciplines?” Or: “But, if engineering raises the bar, won’t young people select other professions?” (Note: With respect to the second question, they are and most of those professions have already raised the bar higher than engineering.)

These questions raise some broader human behavior questions that warrant attention. What happens when expectations are raised in our personal, professional, community, and other lives? What happens personally and organizationally when expectations remain fixed or decline, when the bar stays in place or is lowered? What kind of people are attracted to a raised bar and what kind are repelled by it?

As a middle school student, I remember learning about the insurmountable four-minute mile—no one could do it. Then, on May 6, 1954, the Englishman Roger Bannister ran a 3:59.4 mile. The raised bar immediately attracted the best of runners. Within a month, the Australian John Landy beat Bannister’s time and later that summer, in a widely publicized race, Bannister, with a time of 3:58.9, beat Landy. A half-century later, the four-minute mile is the standard for male runners. Many, including high school athletes, have run sub-four-minute miles with some having accomplished this feat over 100 times. In summary, the mile bar was raised, the best runners responded, and new records were set.

At one point in my career, I served as the dean of a small engineering college. My duties included meeting with prospective engineering students and their parents. This particular young lady, probably a high school senior, was doing her homework about professions—engineering,
medicine, law, and business. She asked me how many years were required to earn an engineering
degree. I proudly told her that, at least in our program, the average completion time was
essentially four academic years. Her reply, which was something like, “if it only takes four years,
it can’t be worth much,” surprised me and later caused me to reflect. Her view suggested to me
then, as it does now, that young people—specially bright, ambitious young people—may view
longer, more rigorous academic programs as an asset, not a liability.

What happens in our personal life when the bar is raised? Do we respond by going elsewhere or
are we attracted to the challenge and rise to the occasion. Depends in part, on who “we” is.
Recall those multiple section college courses when you had a choice of professors. Typically one
professor was known as being well prepared, having high expectations for his or her students,
and being supportive. The other professors were, as we used to say then, “easy.” What kind of
students selected the section taught by the “hard prof”? Most of you know because you were in
that section. You and some of your fellow students were bright, ambitious, diligent, and
appreciative of the special learning opportunity offered by the “hard prof.” Similar self-selection
occurred when the department, college, or university offered extra opportunities such as
independent studies, honors courses, undergraduate research, and international study.

While I realize that individual anecdotes like the preceding prove nothing, cumulative experience
teaches that a raised bar becomes a magnet for the “best and brightest.” Reforming engineering
or portions of engineering, by elevating the education and early experience expectations will, in
my view, attract even higher caliber young people to the entire profession, or at least to those
reformed, more demanding portions of the profession. Numbers of students may drop, either
temporarily or permanently, but the goal is quality, not quantity. Writer and editor Paul
Dickson reminds us “If you want a track team to win the high jump, you find one person who
can jump seven feet, not seven people who can jump one foot.” Engineering programs at some
universities may go by the wayside. Again, our interest should be in improvement, in reform, and
in the quality of offerings. U.S. engineers must offer added value to compete in an increasingly
globalized society. Playing a numbers game is a sure way to lose the global competition.

During the last century, other professions reformed the content and length of their educational
and other requirements. Examples are accounting, architecture, audiology, dentistry, law,
medicine, nursing, optometry, pharmacy, and veterinary medicine. Consider, as an example, the
raise the bar experience of the accounting profession which began implementation, in the 1980s,
of a requirement to complete 150 semester credit hours as a condition for sitting for the CPA
examination. Forty-four states and the District of Columbia, Guam, and Puerto Rico have
adopted this criterion. National accounting enrollments have been increasing since about 2000
although difficulty in finding faculty has become a constraint. For example, for the period 2001
to 2005, total enrollments in accounting bachelors programs in three Maryland universities
increased 15 to 20 percent per year. While views continue to vary among accounting educators
and employers across the country, the predominant thinking is that the additional education has
the potential to strengthen the profession, especially when delivered in re-designed and
integrated curricula or separate master’s degree programs.

And, what has engineering done? Our four-year engineering education model, paralleling the
four-year liberal arts model, dates back 200 years to the 1802 founding of the first U.S.
engineering program at West Point. Other professions, some of which started their formal education after engineering and in a more modest manner, have passed us by in duration, breadth, and depth of formal education required for professional practice.

Perhaps engineering can take some comfort in not having lowered the bar. Assume, in spite of the reduced number of credits required for the bachelor’s degree, shortened semesters, and grade inflation, that the engineering bar has not been lowered. However, when other professions raise their bars, our profession’s bar is, in a relative sense lowered. And, let’s not think that the most qualified young people don’t notice.

However, the future is bright. As indicated earlier in this article, engineering reform has begun. Disciplines that pioneer the reform effort may experience a decline in the number of students they attract—a loss of those young people who seek an easier route. More importantly, the pioneering disciplines will attract a larger absolute number of bright, ambitious, diligent, and appreciative students who want a career whose educational and other programs prepare them for a challenging and satisfying career in the 21st Century.

And those students will increasingly include women who are now grossly under represented in our engineering schools. Low participation by women in engineering, relative to society and relative to other professions such as business, law, and medicine, is one of our profession’s most serious problems. I know we are officially concerned about the long term under-representation of women and some minorities in engineering.

I believe we should be embarrassed! What is wrong with us as a profession—as a group of academics and practitioners doing important work—when less than 20 percent of our students are women while females make up almost 60 percent of the undergraduate population? Perhaps a significant number of bright young women, like the high school student I mentioned, view engineering as too easy, as not worthy of their attention given the profession’s limited educational expectations relative to essentially all other professions.

A profession cannot prosper when it “effectively cuts itself off from half of its potential talent pool.” Balancing the equation is not just about girls and women, it is about harnessing the intellectual capital in future leadership in science, engineering, and technology.” The good news is that as a result of raising the bar, portions of engineering will begin to draw more evenly on both halves of the talent pool, not just primarily the male half, and as a result significantly strengthen their disciplines.

YOUR POSSIBLE ROLE

Assume, in keeping with the first and second purpose of this article, you agree that reform is needed and that significant segments of U.S. engineering are heading in a new direction and you want to contribute, or contribute more to the effort. Maybe experience has taught you the essence of philosopher Arthur Schopenhauer’s thought that “all truth goes through three stages. First it is ridiculed, then it is violently opposed, finally it is accepted as self-evident.” The need for and the beginnings of reform are, in my view, and perhaps yours, self-evident.
How could you become an active or more active participant, a contributor? The short answer is “many ways” and don’t wait to be invited. Recognize that the reform movement described in this article has been and will continue to be essentially volunteer driven and volunteer staffed. As succinctly stated by engineer Richard Weingardt, “the world is run by those who show up.” The longer answer to the “what could you do” question follows in the form of possible concrete “show up” actions.

- Come up to speed, if much of this is new to you, by reviewing some key documents cited in this article. They are available at no cost via the web. Perhaps your department or group, whether in an engineering company, public agency, or university, could devote some quality time to discussing key documents.

- Communicate with your discipline-oriented society’s educational committee or board (e.g., the IEEE Educational Activities Board) and determine their position on, and efforts toward, reform. Having served on such volunteer groups, I know that some have a heavy load of routine work and may not be devoting resources to new initiatives. Find out. Offer to help.

- Invite a reform leader to speak at a meeting of your professional society. You will find their names and contact information in the previously mentioned key documents or through your professional society. They typically welcome opportunities to present status reports and obtain input for what is typically an evolving reform process.

- Contact faculty at your alma mater or a university where you, as a private or public sector practitioner, recruit engineers. Ask them how they view the reform effort and offer to assist.

- Express your views in a letter to the editor or an opinion column in your professional society’s newsletter, magazine, or journal. Or, better yet, write an article. As noted by publisher Malcolm Forbes, “Putting pen to paper lights more fires than matches ever will.”

- Present a paper at an appropriate conference, such as the Annual American Society for Engineering Education Conference and Exposition, or a conference of your specialty engineering society. Preparing for and delivering a presentation and then interacting with the audience enables you to articulate and test your views. Playwright Edward Albee shared this thought: “I write to find out what I think.”

- Determine your licensing board’s position on the Model Law and urge them to discuss its implications for the future of professional engineering. Maybe your state or territory can be a leader in implementing the NCEES Model Law.

- If you are a member of an engineering faculty, brief your department, other departments, and/or advisory boards on recent reform developments (e.g., give them this paper) and request their views and support in implementing major changes within your college.
CONCLUDING THOUGHTS

Our profession has only two futures, the one we create for ourselves or, in the “vacuum” of inaction and reaction, the one others create for us. As an entire profession, or as components of a profession, we can either continue to be largely reactive or we can transform ourselves by becoming proactive.

Some of you may be uncomfortable with the stated one or the other proposition. You dislike extremes—you prefer a middle ground. In my view, a middle ground won’t suffice given what is at stake, namely attracting the highest quality young people to engineering, meeting society’s increasingly complex environmental and infrastructure needs, and dealing with rapid change around the globe. As a profession, our collective mindset must be one of being in charge of our destiny, of being the windshield and not the bug.

Consistent with the first and second purposes of this paper, I have reviewed the need for reform in the education and early experience of U.S. engineers and have shown that some elements of the U.S. engineering profession are proactively creating their futures by reforming the education and early experience of engineers and taking other actions. They are succeeding; they are seeing benefits. However, engineering, and more importantly, society would be better served if the entire profession embarked on reform in keeping with the earlier, pan-engineering, visionary calls.

Consistent with the third purpose of this paper, possible roles for you are suggested. To reiterate, if you, as an academic or practitioner, are not already involved, please consider joining the reform effort and encouraging others to do the same. If little is happening, start the reform of your department, college, professional society, or other organization. You may initially feel powerless or even intimidated because you are only one person in your department, or you and your colleagues are only a handful in your college, or your reform-minded group is miniscule in number relative to the size of your professional society. Even if you oppose the reform that is now underway, get involved.

Vision, commitment, and teamwork are the necessary ingredients for reform, not large numbers. As wisely stated by anthropologist Margaret Meade and has been demonstrated by the reform that is now underway, “Never doubt that a small group of committed people can change the world. It is the only thing that ever has.”
NOTES AND CITED SOURCES


22. Only 19 percent of the 2006 engineering bachelor’s degree recipients were women, the lowest representation in the last decade, even though women comprise 57 percent of the undergraduate population. See Loftus, M. 2007. “Why Won’t She Listen?,” *PRISM*, ASEE, December, pp. 26-31.


25. Robert Frost’s poem, “The Road Not Taken” is interpreted here as meaning that taking the road less traveled resulted in a positive “difference,” a very favorable result. Over the years, some readers challenged this interpretation. For example, some interpret Frost as saying that the two roads were similar. However, the traveler, having chosen one, committed to having it become the best choice. See, for example, Schwehn, M. R. and D. C. Bass. 2006. Leading Lives That Matter, Chapter 7, “How Shall I Tell the Story of My Life?,” William B. Eerdmans Publishing Company, Grand Rapids, MI.


29. While the BOK clearly prescribes levels of achievement for each of the outcomes, the detailed means to achieve those levels is not prescribed. That is, the outcomes are presented without consideration of courses, semesters, faculty expectations, co-curricular and extra-curricular activities, access and delivery systems, employer’s education and training programs, and other administrative and logistical aspects of teaching and learning during education and early experience.

30. Engineers are licensed in 50 states plus the District of Columbia and four U.S. territories (Guam, Puerto Rico, Northern Mariana Islands, and the Virgin Islands) for a total of 55 licensing jurisdictions. Illinois has a separate board for structural engineering. Therefore, there are 56 boards that license engineers. For an historical account of U.S. engineering licensure, see McGuirt, D. 2007, “The Professional Engineering Century,” PE, June, pp. 24-29 and for thoughts on the future of licensure, see Nelson, J. D. and B. E. Price, 2007, “The Future of Professional Engineering Licensure, PE, June, pp. 30-34.


Construction, and Environmental Engineering unanimously embraced the ASCE Policy Statement 465 and the BOK, the undergraduate curriculum was restructured to incorporate the BOK, and pre-college recruitment includes advice to pursue a master’s degree. Some results four years into the effort: Doubled undergraduate enrollment and increased student quality based on high school GPA and ACT/SAT scores.

34. Brannan, K. P., Head, Department of Civil and Environmental Engineering, The Citadel, January 21, 2008, personal communication. The ASCE BOK forms the core of the department’s ABET assessment process. The BOK outcomes were adopted in 2005 to reflect the skills and attributes all civil engineering students were expected to fulfill by graduation. Outcomes map the department’s Program Educational Objectives of design, sustainable success, and broad based education.

35. Lange, D., Associate Department Head, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, January 24, 2008, personal communication. The department’s Curriculum Committee, in response to BOK themes, is revising its undergraduate and Master of Science curricula in anticipation of greater demand for the MS program. Changes include better integration of professional issues in undergraduate courses, earlier exposure to laboratories and learning by doing, greater accommodation of study abroad and undergraduate research, a more streamlined MS curriculum, and improved academic advising.

36. Carpenter, D., Department Assessment Coordinator, Department of Civil Engineering, Lawrence Technological Institute, January 29, 2008, personal communication. The BOK as presented in ASCE’s Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future – Second Edition is being used as the basis for curricular improvements in anticipation of the 2010 ABET visit.

37. Sutterer, K. G., Department of Civil Engineering, Rose-Hulman Institute of Technology, January 27, 2008. The department found that its undergraduate program was almost aligned with the BOK, used the BOK as assessment tool in preparing its last ABET report, and is planning for a master’s degree.

38. Welch, R. W., Chair, Department of Civil Engineering. The University of Texas at Tyler, February 5, 2008, personal communication. The curriculum has been adjusted to reflect the first edition of the BOK. For example, senior level courses now include leadership, business practice, public policy, and asset management modules. Bloom’s Taxonomy is well grounded in each course. Every student is encouraged to earn a master’s degree so that they acquire the technical depth called for in the BOK.

39. Elliot, T., Department ABET Facilitator and member of College ABET Committee, Department of Civil and Environmental Engineering, University of Utah, December 24 and 27, 2007, personal communication. Results of the first edition of the BOK have been used to eliminate ambiguity in levels of achievement criteria; to obtain quasi faculty communication positions; to respond to Industrial Advisory Board concerns; and to enable the department to assume a leadership role in the college. In addition, the College ABET
Committee approved the BOK as the baseline planning document for preparing for the next ABET evaluation in 2009.

40. ASCE formed the BOK Experiential Fulfillment Committee in 2008 and charged it to prepare guidelines to assist engineer interns to fulfill BOK outcomes through on-the-job experience, education, and training.

41. ASME, “Global Summit on the Future of Mechanical Engineering,”
http://www.asmeconferences.org/asmeglobalsummit.


44. Since ASCE adopted Policy Statement 465 in October, 1998, undergraduate civil engineering enrollment rose 31 percent, from 36,281 to 47,524 in 2006, the last year for which data are available and a record high. The cause is not known. Source: Engineering Workforce Commission. 2007. Engineering and Technology Enrollment – Fall 2006, American Association of Engineering Societies.


Appendix A: Entry into the practice of civil engineering at the professional level requires fulfilling 24 outcomes to the appropriate levels of achievement.

<table>
<thead>
<tr>
<th>Outcome number and title</th>
<th>Level of achievement</th>
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<tbody>
<tr>
<td></td>
<td>1 Knowledge</td>
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<tr>
<td>1. Knowledge</td>
<td>B B B</td>
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<tr>
<td>2. Comprehension</td>
<td>B B B</td>
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<tr>
<td>3. Application</td>
<td>B B B</td>
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<td>4. Analysis</td>
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<tr>
<td>5. Synthesis</td>
<td>B B B</td>
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<tr>
<td>6. Evaluation</td>
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</table>

**Foundational**

1. Mathematics
2. Natural sciences
3. Humanities
4. Social sciences

**Technical**

5. Materials science
6. Mechanics
7. Experiments
8. Problem recognition and solving
9. Design
10. Sustainability
11. Contemp. Issues & hist. perspectives
12. Risk and uncertainty
13. Project management
14. Breadth in civil engineering areas
15. Technical specialization

**Professional**

16. Communication
17. Public policy
18. Business and public administration
19. Globalization
20. Leadership
21. Teamwork
22. Attitudes
23. Lifelong learning
24. Professional and ethical responsibility

**Key:**

- **B**: Portion of the BOK fulfilled through the bachelor's degree
- **M/30**: Portion of the BOK fulfilled through the master's degree or equivalent (approximately 30 semester credits of acceptable graduate-level or upper-level undergraduate courses in a specialized technical area and/or professional practice area related to civil engineering)
- **E**: Portion of the BOK fulfilled through the prelicensure experience

Note: For additional information, including an outcomes rubric and explanations of each of the outcomes, refer to *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future – Second Edition.*

/ASEEILIN