Visions of the Future of Engineering Education: Sharpening the Focus

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Abstract

Over the last several years, a number of engineering organizations have postulated visions of engineering education beyond 2020. In 2005, the National Academy of Engineering published *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*[1]. Soon thereafter, ASCE released *The Vision for Civil Engineering in 2025*[2] followed by *Achieving the Vision for Civil Engineering in 2025, A Roadmap for the Profession*[3] in 2008.

Mechanical engineers went through a similar visioning process in 2008 with *2028 Vision for Mechanical Engineering: A report of the Global Summit on the Future of Mechanical Engineering*[4] followed by *Vision 2030: Creating the Future of Mechanical Engineering Education*[5] in December 2011.

In 2012 the National Academy of Engineering convened a distinguished panel of experts in Washington, DC, for a forum entitled "Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning." And the dialogue continues into the present. In late October 2013, the National Academy of Engineering convened its annual symposium "Frontiers of Engineering Education" in Irvine, California.

This scholarly paper will delve into a series of questions about the future of engineering education including:

- What do various visions for the future of engineering education have in common?
- How are the various visions distinct from each other?
- How might the various engineering societies collaborate to realize their visions of engineering education in the future (perhaps through the AAES Working Group on Engineering Education)?
- Since 2020 is only six years away, is it time to take another look at the future of engineering education?

In characterizing one aspect of a future state of civil engineering practice, ASCE's roadmap to achieving Vision 2025 declares, "Civil engineering is universally recognized as a 'learned profession' characterized by competency and the continued pursuit knowledge and experience." Engineering societies can work together to make this a reality for all branches of engineering.

Background

Visualizing the future of engineering education is not a new phenomenon. During the 1920's the Society for the Promotion of Engineering Education developed the landmark study[6], "Report of the Investigation of Engineering Education, 1923-1929", that has been popularly referred to as the Wickenden Report. Interestingly enough, over 80 years ago they were discussing "the question of a longer engineering curriculum" along with programs, standards and facilities required. We have come a long way since the late 1920's and today are contemplating what engineering education needs might be appropriate to the 2020's and beyond.

The vision for the future of civil engineer profession on a global scale is enunciated in the publication *The Vision for Civil Engineering in 2025* which imagines an end state where "Led by civil engineers, the global engineering profession has implemented broad changes to the academic prerequisites to professional practice. Today, those seeking admission to the professional practice of engineering must demonstrate that they have fulfilled the appropriate body of knowledge through education and experience. Gaining acceptance of the body of knowledge concept has taken more than 20 years, but is now common practice throughout much of the world[7]."

Even domestically in the United States, educators are recognizing the limitations of a four-year baccalaureate degree in preparing tomorrow's professional engineers. As quoted in *The Engineer of 2020: Visions of Engineering in the New Century* "It is evident that the exploding body of science and engineering knowledge cannot be accommodated within the context of the traditional four-year baccalaureate degree[8]."

Purpose and Scope

The objective of this paper is to briefly review several developments in the future visioning of engineering education and explore the commonalities and differences between them. The American Society of Civil Engineers (ASCE) is a key stake holder in the future of engineering education.

This paper specifically looks at the following programs or publications related to the future of engineering education.

1. *Millennium Project – Engineering for a Changing World, A Roadmap to the Future of Engineering Practice, Research, and Education*
2. *National Academy of Engineering – The Engineer of 2020, Visions of Engineering in the New Century and Educating the Engineer of 2020: Adapting Engineering Education to the New Century*
3. *5XME and American Society of Mechanical Engineers –Vision 2028 and Vision 2030*
4. *American Society of Civil Engineers – The Vision for Civil Engineering in 2025, Achieving the Vision for Civil Engineering in 2025, A Roadmap for the Profession in 2008* and *The 21st-Century Engineer: A Proposal for Engineering Education Reform.*

Note that the views and opinions expressed in this paper are the author's and do not necessarily reflect ASCE policy or the policies of the other entities envisioning the future of engineering education.

Engineering for a Changing World, A Roadmap to the Future of Engineering Practice, Research, and Education

As part of the Millennium Project at the University of Michigan and under the leadership of Dr. James J. Duderstadt, President Emeritus and University Professor of Science and Engineering, the University of Michigan developed a proposed vision for the future of engineering education in 2008 that included the following objectives[9]:

1. *To establish engineering practice as a true learned profession, similar in rigor, intellectual breadth, preparation, stature, and influence to law and medicine, with an extensive post-graduate education and culture more characteristic of professional guilds than corporate employees.*

2. To redefine the nature of basic and applied engineering research, developing new research paradigms that better address compelling social priorities than those methods characterizing scientific research.

3. To adopt a systemic, research-based approach to innovation and continuous improvement in engineering education, recognizing the importance of diverse approaches–albeit characterized by quality and rigor–to serve the highly diverse technology needs of our society.

4. To establish engineering as a true liberal arts discipline, similar to the natural sciences, social sciences, and humanities (and the trivium, quadrivium, and natural philosophy of earlier times), by imbedding it in the general education requirements of a college graduate for an increasingly technology-driven and -dependent society of the century ahead.

5. To achieve far greater diversity among the participants in engineering, the roles and types of engineers needed by our nation, and the programs engaged in preparing them for professional practice.

As described on the University website, "the Millennium Project is a research center at the University of Michigan concerned with the impact of technology on our society, our communities, our institutions, and our planet."

The report advocates for new knowledge and new skills for engineers and states "Broadly speaking, the most daunting challenges facing the nation–global competitiveness, health care delivery to an aging population, energy production and distribution, environmental remediation and sustainability, national and homeland security, communications, and transportation–all pose complex systems challenges that require both new knowledge and new skills for engineering practice".

To achieve the aforementioned objectives, the report concludes by suggesting seven proposals to transform engineering education and the very profession of engineering:

"Proposal 1: Engineering professional and disciplinary societies, working with engineering leadership groups such as the National Academy of Engineering, the National Society for Professional Engineers, the American Association of Engineering Societies, ABET, and the American Society for Engineering Education, should strive to create a "guild-like" culture in the

engineering profession, similar to those characterizing other learned professions such as medicine and law, that aims to shape rather than simply react to market pressures.

Proposal 2: The federal government, in close collaboration with industry, higher education, and the states, should launch a large number of Discovery Innovation Institutes at American research universities with the mission of linking fundamental scientific discoveries with technological innovation to build the knowledge base essential for new products, processes, and services to meet the needs of society.

Proposal 3: Working closely with industry and professional societies, higher education should establish graduate professional schools of engineering that would offer practice-based degrees at the post-baccalaureate level as the entry degree into the engineering profession.

Proposal 4: Undergraduate engineering should be restructured as an academic discipline, similar to other liberal arts disciplines in the sciences, arts, and humanities, thereby providing students with more flexibility to benefit from the broader educational opportunities offered by the comprehensive American university, with the goal of preparing them for a lifetime of further learning rather than simply near-term professional practice.

Proposal 5: In a world characterized by rapidly accelerating technologies and increasing complexity, it is essential that the engineering profession develop a structured approach to lifelong learning for practicing engineers similar to those in medicine and law. This will require not only a significant commitment by educators, employers, and professional societies but possibly also additional licensing requirements in some fields.

Proposal 6: The academic discipline of engineering (or, perhaps more broadly, technology) should be included in the liberal arts canon undergirding a 21st-century college education for all students.

Proposal 7: All participants and stakeholders in the engineering community (industry, government, institutions of higher education, professional societies, et. al.) should commit the resources, programs, and leadership necessary to enable participation in engineering to achieve a racial, ethnic, and gender diversity consisted with the American population."

The Engineer of 2020, Visions of Engineering in the New Century and Educating the Engineer of 2020: Adapting Engineering Education to the New Century

The National Academy of Engineering's (NAE) *The Engineer of 2020: Visions of Engineering in the New Century*[10] *notes that* "Almost all discussion of educating the engineer of 2020 presumes additions to the curriculum—more on communications, more of the social sciences, more on business and economics, more cross-cultural studies, more on nano-, bio-, and information technologies, more on the fundamentals behind these increasingly central technologies, and so forth. Unfortunately, the typical undergraduate engineering program already requires around 10 percent more coursework than other degree programs, and a typical engineering student needs 4.8 years to complete it. Simply adding these new elements to the curriculum is not an option. The options would seem to be: (a) cutting out some of the current requirements, (b) restructuring current courses to teach them much more efficiently, or (c) increasing the time spent in school to become an engineering professional. All three may need to be done to some extent, but it is worth noting that all professions except engineering—business, law, medicine—presume that the bachelor's degree is not the first professional degree. They presume the first professional degree is preceded by a nonspecialist liberal arts degree, so it is also not clear that just adding two years or so to a traditional engineering B.S. degree will raise engineers to the professional status of managers, lawyers, and doctors. Nonetheless, while it cannot be mandated instantly and could require radical restructuring of the present approach to engineering education, by 2020 engineering could well follow the course of the other professions. Doing so may be part of the competitive edge of U.S. engineers."

Another area emphasized in the report is sustainability. It states "Engineering practices must incorporate attention to sustainable technology, and engineers need to be educated to consider issues of sustainability in all aspects of design and manufacturing."

NAE's subsequent publication *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*[11] produced a 58 page report supplemented with 11 additional essays and papers. The report produced 14 recommendations as summarized below:

1. *"The baccalaureate degree should be recognized as the "pre- engineering" degree or bachelor of arts in engineering degree, depending on the course content and reflecting the career aspirations of the student.*
2. *ABET should allow accreditation of engineering programs of the same name at the baccalaureate and graduate levels in the same department to recognize that education through a "professional" master's degree produces an AME, an accredited "master" engineer.*
3. *Engineering schools should more vigorously exploit the flexibility inherent in the outcomes-based accreditation approach to experiment with novel models for baccalaureate education. ABET should ensure that evaluators look for innovation and experimentation in the curriculum and not just hold institutions to a strict interpretation of the guidelines as they see them.*
4. *Whatever other creative approaches are taken in the four-year engineering curriculum, the essence of engineering—the iterative process of designing, predicting performance, building, and testing—should be taught from the earliest stages of the curriculum, including the first year.*
5. *The engineering education establishment, for example, the Engineering Deans Council, should endorse research in engineering education as a valued and rewarded activity for engineering faculty as a means to enhance and personalize the connection to undergraduate students, to understand how they learn, and to appreciate the pedagogical approaches that excite them.*
6. *Colleges and universities should develop new standards for faculty qualifications, appointments, and expectations, for example, to require experience as a practicing engineer, and should create or adapt development programs to support the professional growth of engineering faculty.*

7. *As well as delivering content, engineering schools must teach engineering students how to learn, and must play a continuing role along with professional organizations in facilitating lifelong learning, perhaps through offering "executive" technical degrees similar to executive MBAs.*
8. *Engineering schools introduce interdisciplinary learning in the undergraduate environment, rather than having it as an exclusive feature of the graduate programs.*
9. *Engineering educators should explore the development of case studies of engineering successes and failures and the appropriate use of a case-studies approach in undergraduate and graduate curricula.*
10. *Four-year engineering schools must accept it as their responsibility to work with their local community colleges to ensure effective articulation, as seamless as possible, with their two-year programs. Graduate students from all over the world have flocked to the United States for years to take advantage of the excellent graduate education available.*
11. *U.S. engineering schools must develop programs to encourage/ reward domestic engineering students to aspire to the M.S. and/or Ph.D. degree.*
12. *Engineering schools should lend their energies to a national effort to improve math, science, and engineering education at the K-12 level.*
13. *The engineering education establishment should participate in a coordinated national effort to promote public understanding of engineering and technology literacy of the public.*
14. *NSF should collect and/or fund collection, perhaps through ASEE or the Engineering Workforce Commission, of comprehensive data by engineering department/school on program philosophy and student outcomes such as, but not exclusively, student retention rates by gender and ethnicity, common reasons why students leave, where they go, percent of entering freshman that* graduate, time to degree, and information on jobs and admission to graduate school."

Note that progress has been made on several of these recommendations. For example in March of 2008, the prohibition on dual level accreditation (item 2 above) was removed by ABET. From ASCE's perspective, the recommendations envisioned in item's 1 and 11 would particularly be supportive of efforts to "Raise the Bar" on engineering licensure.

5XME and American Society of Mechanical Engineers –Vision 2028 and Vision 2030

A multiyear effort to transform mechanical engineering education began in 2007 with a workshop entitled "*5XME Workshop: Transforming Mechanical Engineering Education and Research in the USA*[12]". Another workshop was held November 12-14, 2009 in Lake Buena Vista, Florida in conjunction with the American Society of Mechanical Engineers (ASME) International Mechanical Engineering Congress and Exposition (IMECE)[13]. The term 5XME relates to the concept that engineering talent abroad may cost one-fifth of such services in the United States, thus American engineers much provide five times the value or more to remain competitive. The first workshop concluded that:

1. "In today's global knowledge economy, mechanical engineers educated in the USA must be able to add significantly more value than their counterparts abroad, through the breadth of their intellectual capacity, their ability to innovate, and their leadership in addressing major societal challenges.

2. The bachelors degree should introduce engineering as a discipline, and should be viewed as an extension of the traditional liberal arts degree where education in natural sciences, social sciences and humanities is supplemented by education in the discipline of engineering for an increasingly technological world.

3. This bachelors degree in the discipline of engineering can be viewed as the foundational stem upon which several extensions can be grafted: (1) continued professional depth through a professional masters degree in engineering, and (2) transition to non-engineering career paths such as medicine, law, and business administration.

4. The masters degree should introduce engineering as a profession, and become the requirement for professional practice. This is where educational institutions and professional societies can build an awareness of the profession, as opposed to producing graduates who view themselves merely as employees.

5. Doctoral education in engineering is essential to national prosperity, and global competition is rapidly increasing. The doctoral degree in engineering, while indisputably the best in the world, needs to be enhanced and strengthened with an emphasis on breadth as well as depth, linking discovery and innovation, and improved leadership and teaching skills.

6. Lifelong learning programs in engineering, including executive education, need to be developed and delivered to engineers at all stages in their professional development."

Several of the participants in the 5XME workshops continued to work on ASME's subsequent visioning process around mechanical engineering education. The 5XME conclusions are very consistent with visions of the future developed by civil engineers as outlined later in this paper.

In 2008, ASME produced *2028 Vision for Mechanical Engineering: A report of the Global Summit on the Future of Mechanical Engineering*[14] based on a mechanical engineering summit. ASME invited more than 120 engineering and science leaders from 19 countries representing industry, academia and government to Washington, DC in April of 2008 to "imagine what mechanical engineering will become between now and 2028." They concluded that to maintain a competitive edge in 2028, "the ability of individuals and organizations to learn, innovate, adopt and adapt faster will drive advanced economies. Mechanical engineering education will be restructured to resolve the demands for many individuals with greater technical knowledge and more professionals who also have depth in management, creativity and problem-solving."

James Duderstadt, President Emeritus and University Professor of Science and Engineering at the University of Michigan made the following observation in the report. "The key to increasing the esteem of engineering, and producing world class engineers, is to broaden engineering education so that it is comparable to other established professions like architecture and law. Moving forward there is a need to build a "guild culture" of professionals who identify more with the profession itself than with their individual employers. This would require a more systematic approach to education with greater emphasis on completing graduate-level professional schools of engineering.

However, an alternate but complementary future scenario could occur. In this future, the profession of engineering relies more on technicians that take on many of the routine technical tasks. This would parallel changes in the medical profession where “physician extenders” are taking over many routine tasks for medical doctors. Mechanical engineers with advanced degrees would spend a higher amount of their time troubleshooting very difficult technical issues, managing complex systems and overseeing the work of technicians. This would mirror trends already seen in outsourcing many engineering tasks and the growth of engineering technicians.”

In 2008, the ASME Vision 2030 Task Force was created to:

- assess the state of ME education,
- provide specific recommendations for improving mechanical engineering education curricula, and
- advocate for their adoption[15].

As described by Danielson[16], “the ASME Vision 2030 Task Force pursued two primary objectives: help define the knowledge and skills that mechanical engineering or mechanical engineering technology graduates should have to be globally competitive, and, to provide, and advocate for their adoption, recommendations for mechanical engineering education curricula, with the goal of providing graduates with improved expertise for successful professional practice.”

In pursuing their objectives, the task force held workshops and seminars at ASME Engineering Education Conferences and did extensive surveying of academic and industrial stakeholders as well as early career engineers. Ultimately the task force working with the ASME Center for Education published *Vision 2030 Creating the Future of Mechanical Engineering Education*[17]. The report made several key recommendations including:

1. *“Create curricular flexibility. A more flexible, holistic undergraduate curriculum with a strong professional skills component integrated across the curriculum is envisioned. The curriculum should include major active, discovery-based learning opportunities such as a design spine or other experiences. The curriculum should emphasize problem solving over factual knowledge and include systems level experiences. Breadth is most important, with depth possible in a particular area of the student’s choosing.*

2. *Constrain the undergraduate program. It is not necessary to add courses or content to the nominal 120 – 128 semester hour, four year baccalaureate degree program. However, there must be more effective use of existing technical content, the general education program, and extracurricular activities. Recognizing that the four-year engineering education program described above will not contain as much technical content, we suggest that undergraduate programs be designed with the expectation that most technical specialization and depth will come later. Strong articulation with graduate programs is warranted as the nature of graduate education may change due to a differently educated undergraduate entering a graduate program.*

3. *Create a professional educational paradigm. Develop a professional school attitude among students in the undergraduate program. Replace some factual, technical information with professional skills that should be integrated throughout the curriculum, and broaden the skill set to include topics such as global understanding and communication, cultural awareness and leadership.*

4. *Create a curriculum that inspires innovation. Develop curricula that develop the innate creativity and leadership potential within every student. Such curricula must encourage and provide opportunities for active, discovery-based learning, and provide opportunities for not only success, but failure. These curricula should give every student the skill set for leadership and the opportunity to lead at some level. These curricula could, at one level, give every the student the skills and confidence needed so that he or she could start their own company. Topics such as engineering as a part of the business process, entrepreneurship, and leadership become essential.*

5. *Advocate for success. ASME's corporate position in education must be aligned with proposed reforms and the broad communication of goals and methods of reform accomplished to essential constituencies inside, and outside, of ASME and the educational community. In particular, championing the critical role of mechanical engineering and the need for mechanical engineering leadership in creating a sustainable future with a high quality of life for all must become a high priority."*

ASCE Vision 2025 and the 21st-Century Engineer

As described by ASCE, the *Vision for Civil Engineering in 2025* and *Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession* mark the culmination of almost eight years of effort to redefine what it will mean to be a civil engineer in the world of the future. Vision 2025 represents the collective wisdom of more than 60 experts from around the world who participated in the Summit on the topic and presents an aspirational vision for what the future can and should be. Numerous individual civil engineers and civil engineering organizations around the world have embraced this appeal for a new, enhanced role for the profession. They call on civil engineers to control their own destiny rather than letting events control it for them. The document was translated into several languages further illustrating the worldwide appeal this program has.

The vision developed as a result of the Summit is:

> *"Entrusted by society to create a sustainable world and enhance the global quality of life, civil engineers serve competently, collaboratively, and ethically as master:*
>
> - *planners, designers, constructors, and operators of society's economic and social engine—the built environment;*
> - *stewards of the natural environment and its resources;*
> - *innovators and integrators of ideas and technology across the public, private, and academic sectors;*
> - *managers of risk and uncertainty caused by natural events, accidents, and other threats; and*
> - *leaders in discussions and decisions shaping public environmental and infrastructure policy."*

The *Vision for Civil Engineering in 2025* sets the stage by stating that "..The increasing breadth, complexity, and rate of change of professional practice— all put greater emphasis not only on continuing education but also on what a basic civil engineering education must deliver up front. The body of knowledge necessary to effectively practice civil engineering at the professional level is beyond the scope of the traditional bachelor's degree, even when coupled with the mandated early-career experience. Education must meld technical excellence with the ability to lead, influence, and integrate—preparing the engineer to weigh the diverse societal issues that shape the optimal approaches to planning, design, and construction[18]." At the time this was published, ASCE had recently developed (in 2004) *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*[19]. The document identified 15 desirable outcomes to be fulfilled through a combination of formal education and practice. Four years later, a second edition with the same title was published[20] and contained 24 desirable outcomes which provided more detailed clarification to the 15 originally proposed. These outcomes are included in Appendix A.

In 2007, one of the Vision 2025 summit participants, ASCE Past President Patricia Galloway wrote *The 21st-Century Engineer a Proposal for Engineering Education Reform*. Galloway states that "in the 21st century, an ever-increasing need will emerge for a holistic breed of engineer—one who can work across borders, cultural boundaries, and social contexts and who can work effectively with nonengineers. As the trend toward a more global and more knowledge-based society continues, the practice of engineering must be changed, and this change must be accomplished through engineering education reform. The engineering curriculum can no longer remain as it has for essentially the past 40 years. The subjects of globalization, diversity, world cultures and languages, communication, leadership, and ethics must constitute a core component of the overall engineering education just as physics and mathematics do."

In concluding her proposal, Galloway says “if engineers are to be adequately prepared to work in a knowledge-based 21st-century society across all borders of the world, there must be an immediate reform in engineering education. What is required is a master’s program that will impart the knowledge and skills required to work within the global economy—knowledge and skills that are not provided at the bachelor’s or master’s level at present. Innovative approaches must be explored to motivate the working engineer to reenter the academic environment. Such approaches include distance learning, cooperative education between academe and industry, and lectures or lecture series delivered by experts in various fields. Although the master’s program I am proposing must be structured within a 30-hour credit requirement, those 30 hours may be completed in nontraditional ways.” She suggests that “The master of professional engineering management is designed to meet the needs of those who are already at work in professional practice—to provide them with the professional skills and knowledge they need to succeed in the 21st-century workplace without requiring them to place their careers on hold while they complete graduate school.”

In *Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession* (Roadmap) in describing a desirable future end state it is foreseen that “Civil engineering is universally recognized as a “learned profession” characterized by competency and the continued pursuit of knowledge and experience.” ASCE recommends that to achieve this, we must embrace a tactic to “Encourage jurisdictions to require sufficient formal education to fulfill an accepted body of knowledge as a prerequisite for licensure, registration, or chartering[21].” The Roadmap also cites the need that “civil engineers are adequately prepared to be proactively and effectively engaged in broad-based public policy discussions” in 2025 and that to accomplish this we must “evaluate the current educational system relative to “proactive problem definition,” including project planning and management, and identify improvements.”

The Roadmap also makes a case for advanced education in several key areas including:

1. *Enabling those in our profession to be “Master Builders – where civil engineers facilitate and lead multi-disciplinary, collaborative programs using a systems approach to achieve successful project outcome” which includes the tactic of “promoting extensive leadership, program management, and project delivery education and training at all levels of career development.”*
2. *Promoting civil engineers as “Stewards of the Environment” where through “the efforts of the global civil engineering profession, civil engineers and the public have recognized and understood the reality of shrinking resources; the necessity for sustainable practices, design, and life-cycle financial support; and the need for social equity in the consumption of resources”. This is supported by a tactic to “Integrate environmental awareness in civil engineering education and practice.”*
3. *Enabling those in our profession to be innovators where “civil engineers define the strategic research direction for leading-edge technologies in the built and natural environment and serve as influential participants and partners in the research process.”*

4. *Producing civil engineering as managers of risk that have "developed innovative approaches, tools, techniques, materials, policies, and business relationships to mitigate the occurrence and effects of both natural and man-made disasters and their associated risks and uncertainties" by the tactic of embedding "risk assessment and risk management methodologies as a core knowledge and skill for civil engineers throughout their education and practice."*
5. *Preparing civil engineers "to be proactively and effectively engaged in broad-based public policy discussions" through a tactic of "evaluating the current educational system relative to "proactive problem definition," including project planning and management, and identify improvements."*

Comparison

We have reviewed visions of the future of engineering education in the 21st century from a handful of different perspectives. We see that enhancing the professional competence of the future engineer is a common theme. Though not all the visionaries might agree on the need for advanced education as a prerequisite to professional licensure, there seems to be common agreement that greater technical specialization and broader communications and policy skills beyond bachelor of engineering programs is warranted for future engineers. Additionally leadership is raised as a key attribute for engineers of the 2020's and 2030's.

Innovation is also identified as a key to the future of engineering education and practice. Innovation appears in each of the four sections above and represents another point of broad consensus. Similarly a working knowledge of sustainability is common across the visions. Other important conclusions of the various visions include a global focus, a commitment to lifelong learning and enhanced communications skills.

We compare the various visions for the future of engineering education in Table 1 below. The interesting conclusion is that there is relative unanimity among the various visions. Hopefully this will help create a deep transformative change in engineering education and further the dialogue between the different societies with respect to the future of engineering education.

As more engineering disciplines develop their own bodies of knowledge (BOK), an area of potential future interest will be how these BOKs compare, particularly on outcomes common to most fields of engineering. The National Society of Professional Engineers recently published the first edition of "The Engineering Body of Knowledge[22]" as applied across all aspects of professional engineering. As stated by NSPE it represents a "first effort on behalf of the profession in defining the knowledge, skills, and attitudes required for the practice of engineering as a professional engineer in responsible charge of engineering activities that may impact public health, safety, and welfare." It along with the civil engineering BOK will provide a valuable reference to other engineering societies that undertake the effort to define engineering discipline specific bodies of knowledge. That exercise may lead such groups to conclude, as ASCE discovered, that it impossible to fit the educationally related portion of the BOK into four short years.

Table 1. Comparison of Engineering Education Visions.

Item*	**Millennium Project**	**Engineer of 2020**	**ASME Visions**	**5XME**	**ASCE Vision 2025 and 21st Century Engineer**
Leadership	**X**	**X**	**X**	**X**	**X**
Innovation	**X**	**X**	**X**	**X**	**X**
Sustainability	**X**	**X**	**X**	**X**	**X**
Education beyond the Bachelor's Degree for Licensure or entry into profession	**X**	**X**		**X**	**X**
Most Technical Specialization at the Graduate Level	**X**	**X**	**X**	**X**	**X**
Lifelong Learning	**X**	**X**	**X**	**X**	**X**
Global Focus	**X**	**X**	**X**	**X**	**X**
Enhanced Communication Skills	**X**	**X**	**X**	**X**	**X**

* Not every vision included the specific items in their final recommendation, but there was sufficient support in the narrative to imply support for the item.

Conclusion

As a key stakeholder in the future of engineering education, ASCE continues to implement and improve its education programs. ASCE recently added a full time director and new department to work with students and younger members to provide for the development and engagement of students through activities and programs that enhance the formal education process and the transition of student members into the profession as ASCE members. Programs in this department include Workshop for Student Chapter Leaders, ASCE Student Conferences, Practitioner & Faculty Advisor Training Workshop, and various student competitions.

Additionally, the ASCE Educational Activities Department oversees many important programs such as

1. ABET Accreditation Involvement;

2. CE Faculty Development through the Excellence in Civil Engineering Education (ExCEEd);
3. Precollege Outreach; and
4. Civil Engineering Department Heads Programs including an annual conference.

ASCE maintains a very active role in the American Society for Engineering Education (ASEE) Civil Engineering (CE) Division through the ASCE Liaison Committee and continues to publish and present on a variety of education topics every year. ASCE staff is collaborating with the SIG (Special Interest Group) for International Engineering Education under the Corporate Member Council of the ASEE. This group is developing attributes of a global engineer. ASCE also continues to advocate for the full implementation of NCEES Model Law 2020, raising the bar for a professional engineers foundational education to include either a master's degree or an additional 30 upper division or graduate level graduates beyond the ABET accredited bachelor's degree in engineering through its Raise the Bar Initiative.

ASCE also collaborates in a variety of cross society groups such as the American Association of Engineering Societies' Engineering Education Working Group and Licensure Working Group and the NCEES Participating Organizations Liaison Council (POLC). In an ideal situation, the various stakeholders on engineering education will continue to dialogue and work towards a brighter future for engineering education and subsequent practice and licensure.

Appendix A
Civil Engineering Body of Knowledge for the 21st Century – Second Edition
24 Outcomes

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

Bibliography

[1] National Academy of Engineering. 2004. *The Engineer of 2020: Visions of Engineering in the New Century*, NAE, Washington, DC.

[2] American Society of Civil Engineers. 2007. *Vision for Civil Engineering in 2025*. Reston, VA.

[3] American Society of Civil Engineers. 2009. *Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession.* Reston, VA.

[4] ASME Strategic Issues Committee of the Strategic Management Sector as prepared by the Institute for Alternative Futures. 20008. *2028 Vision for Mechanical Engineering: A report of the Global Summit on the Future of Mechanical Engineering*. American Society of Mechanical Engineers.

[5] American Society of Mechanical Engineers (2011). *Vision 2030 – Creating the Future for Mechanical Engineering Education, The Case for Change*. New York, NY.

[6] Wickenden, W. E., 1930. Report of the investigation of engineering education, 1923–1929, Society for the Promotion of Engineering Education, Pittsburgh.

[7] American Society of Civil Engineers. 2007. *Vision for Civil Engineering in 2025*. Reston, VA.

[8] National Academy of Engineering. 2004. *The Engineer of 2020: Visions of Engineering in the New Century*, NAE, Washington, DC.

[9] Duderstadt, James J. 2008. *Engineering for a Changing World, A Roadmap to the Future of Engineering Practice, Research, and Education*. The University of Michigan.

[10] National Academy of Engineering. 2004. *The Engineer of 2020: Visions of Engineering in the New Century*, NAE, Washington, DC.

[11] National Academy of Engineering. 2005. Educating the Engineer of 2020: Adapting Engineering Education to the New Century NAE, Washington, DC.

[12] Ulsoy, A.G. 2007., *5XME Workshop: Transforming Mechanical Engineering Education and Research in the USA*

[13] Ulsoy A. Galip and Kon-Well Wang. *Implementing the Recommendations of the 5xME Workshop Report* from a workshop sponsored by the National Science Foundation (Grant # CMMI 0855698).

[14] ASME Strategic Issues Committee of the Strategic Management Sector as prepared by the Institute for Alternative Futures. 2008. *2028 Vision for Mechanical Engineering: A report of the Global Summit on the Future of Mechanical Engineering*. American Society of Mechanical Engineers.

[15] Kirkpatrick, Dr. Allan. 2013. *ASME Vision 2030 Designing the Future of Mechanical Engineering Education*. From a presentation ASEE College Industry Education Conference, Phoenix, Arizona February 6-8, 2013.

[16] Danielson, Dr. Scott. 2012. AC 2012-4832: ASME'S Vision 2030'S Import for Mechanical Engineering Technology.

[17] American Society of Mechanical Engineers (2011). *Vision 2030 – Creating the Future for Mechanical Engineering Education, The Case for Change*. New York, NY.

[18] American Society of Civil Engineers. 2007. *Vision for Civil Engineering in 2025*. Reston, VA.

[19] American Society of Civil Engineers. 2004. *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*. Reston, VA.

[20] American Society of Civil Engineers. 2008. *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, Second Edition*. Reston, VA.

[21] American Society of Civil Engineers. 2009. *Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession.* Reston, VA.

[22] National Society of Professional Engineers. 2013. *Engineering Body of Knowledge,* Alexandria, VA.