The Case for a Master's Degree for Civil Engineering Licensure

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He is a registered professional civil engineer with extensive background in developing municipal infrastructure projects, and has strong experience in project management and technical staff management for multi-disciplined projects. His BS in Civil Engineering and MBA were both conferred by Lehigh University, Bethlehem, PA.

He has been a loyal supporter and leader in the engineering community. In addition to his extensive service to the American Council of Engineering Companies (ACEC) family, as past national Chairman, and in Pennsylvania, he has been President of the Hazardous Waste Action Coalition (of ACEC); a member of the American Society of Civil Engineers (ASCE) , where he has served on the Raise the Bar Committee; President of the Pennsylvania Society of Professional Engineers; Founding Chairman of the Pennsylvania Design Association Center; and is a Past President of the Engineers' Club of Philadelphia. His is currently serving as President of the Philadelphia Engineering Foundation.

In 2006, Mr. Flicker was named the Delaware Valley Engineer of the Year, as well as Civil Engineer of the Year by the American Society of Civil Engineers- Philadelphia Section.

He is also active in the community. He is a Past President of the Board of Habitat for Humanity- the Affiliates in the Delaware Valley and currently serves on the Board of the Chester County affiliate. He is also a Board Member of the Philadelphia Education Fund/ Philadelphia Scholars and the Public Citizens for Children and Youth (of southeastern Pennsylvania).

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The Case for a Master's Degree for Civil Engineering Licensure

Abstract

For nearly fifty years, different organizations and authors engaged in engineering practice and education have grappled with the adequacy of the baccalaureate degree as preparation for a career in engineering, especially licensed professional practice. Technological advances and expanding societal needs demand that coursework cover more content, while the credit hours required to obtain a bachelor's degree continue to decline. Up until the early 1960's the average engineering curriculum required 145-150 credit hours of coursework. Many programs today have curricula approaching 120 credit hours for a baccalaureate degree.

As far back as 1968, the American Society for Engineering Education (ASEE) authored Goals of Engineering Education[1], funded by the National Science Foundation (NSF). The report concluded:

> *"The increasing complexity of the technological needs of the future… [require] the extension of the basic engineering education to include at least one year of graduate level study."*

In 2004, the National Academy of Engineering (NAE) weighed in on the subject. The Engineer of 2020: Vision of Engineering in the New Century[2] concluded:

> *"We should reconstitute engineering curricula and related engineering programs to prepare today's engineers for the careers of the future."*

In Educating the Engineer of 2020: Adapting Engineering Education to the New Century[3] (published in 2005), NAE reinforced their earlier conclusions with this statement:

> *"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."*

The National Council of Examiners for Engineering and Surveying (NCEES), is the national organization that represents the state licensing boards for professional engineering and surveying across the U.S. In 2015, NCEES approved Position Statement 35 – Future Educational Requirements for Engineering Licensure[4] by a nearly 2:1 ratio. The preamble of the statement says:

> *"One of the goals of NCEES is to advance licensure standards for all professional engineers. Those standards describe the technical and professional competencies needed to safeguard the health, safety and welfare of the public. The council recognizes that the future demands for increasing technical and professional skills have resulted in the need for additional education beyond the bachelor's degree for those entering the engineering profession."*

Since the 1995 Civil Engineering Education Conference in Denver, the American Society of Civil Engineers (ASCE) has continuously advocated for formal post-baccalaureate education for civil engineers who pursue licensure as professional engineers (PEs). By the 2000s, ASCE and several other professional and technical engineering societies had developed "bodies of knowledge" that define the competencies gained by education and experience that they believe are necessary for professional practice. Each of these studies conclude that there is a need for post-baccalaureate engineering education for professional licensure.

These studies focus on competency and on minimum academic and experiential learning necessary for licensed practice, but do not consider the market forces that influence the engineer, the engineer's employer, and society at-large. The purpose of this paper is to do just that. It will answer each of the following questions:

- Does the engineer benefit from higher educational standards?
- Does the employer benefit from higher educational standards?
- Does society benefit from higher educational standards?

Terminology

This paper addresses the licensed professional practice of engineering, not all engineering practice, though many of the arguments can easily apply to all engineering practice. This distinction is made as the roles and responsibilities of professional engineers is better defined and the need for graduate-level engineering education has received more comprehensive study. Consequently, it's important to define certain terms and principles that are foundational for the conclusions presented herein.

The term Professional Engineer

The term "Professional Engineer" is a legal term set in state statute, as only those engineers licensed by a state or U.S. territory can refer to themselves as a Professional Engineer (or PE). The license allows PEs to practice engineering (defined by these same state statutes) involving the protection of public health, safety and welfare where non-licensed engineers cannot. Similar to other professions, licensing is granted state-by-state with varying requirements between states.

A malpractice standard for PEs

Professional engineers, similar to medical doctors, are granted a malpractice standard (by their license). PEs are required to meet a "normal standard of care" when they perform engineering. Normal standard of care generally means that the engineer identified reasonable alternatives to address the problem, analyzed each alternative applying care in the application of math, science and engineering, and came to a logical, rational and justifiable recommendation for a workable solution, not the <u>only</u> solution, as there is never only one solution to an engineering problem. That's the nature of engineering practice.

Licensure affects only 20 percent of all engineers

According to NCEES[5] there are 437,921 resident licenses and 384,654 nonresident licenses (engineers who reside in one state, but hold licenses in one or more other states), which is consistent with estimates that there are approximately 450,000 PEs in the U.S. workforce. ASEE reported that 99,173 bachelor's degrees in engineering were awarded in 2013-14[6]. If we assume that the average over the last 40 years was 60,000 graduates per year and that these individuals are still in the workforce that would equate to 2,400,000 engineers, which means that PEs represent only 20 percent of all engineering graduates. While many of the arguments in this paper can apply to all engineering practice, this is important as the obligations of Professional Engineers are regulated and unique.

A focus on civil engineering practice

This paper further focuses on the minimum educational requirements for professional practice of civil engineering. The authors believe the conclusions reasonably apply to all disciplines, but are most compelling when considering civil engineering practice, where the greatest amount of research on the need for graduate-level engineering education has been performed. To that end, a comparison of the content and character of baccalaureate education for civil, mechanical and electrical engineering - the three primary areas of professional practice - follows.

NCEES offers licensure exams in seven different areas of civil engineering practice: Construction, Geotechnical, Civil/Structural, Transportation, and Water Resources, as well as Structural and Environmental engineering. At the baccalaureate level, civil engineering curricula typically include at least an introduction to each of these areas of practice, as they are interrelated and basic knowledge of one area is generally needed to master another. The broad baccalaureate program provides the basis for specializing in one of these areas of practice when pursuing an advanced degree. The Accreditation Board for Engineering and Technology (ABET) requires "proficiency" in at least three of these areas of practice for accreditation.

NCEES offers licensure exams in only three areas of practice in mechanical and electrical engineering. Mechanical has: HVAC & Refrigeration, Thermal & Fluid Systems, and Mechanical Systems & Materials. Electrical has: Power, Electrical & Electronics, and Computer Engineering. Similar to civil engineering, baccalaureate curricula in mechanical and electrical engineering include introductions to each of these areas of practice, but the civil engineering curriculum is much broader in content.

Civil engineers also pursue licensure at a substantially higher rate than any other discipline. NCEES[7] reports that 62 percent of all PE exams taken in 2013-14 were in civil engineering areas of practice, as shown in Figure 1. However, as estimated by ASEE[8] and shown in Figure 2, civil engineers only represent 13 percent of all engineering graduates in 2013-14.

This is significant, as a large majority of all civil engineering graduates pursue professional licensure, while NCEES data shows that percentages in the mid-teens are more common for mechanical and electrical engineering graduates. Civil engineering programs have consistently had a licensed practice focus, because that is where their graduates seek careers. Mechanical and electrical engineering programs have generally moved much more toward an industry focus as that is where the vast majority of their graduates seek careers.

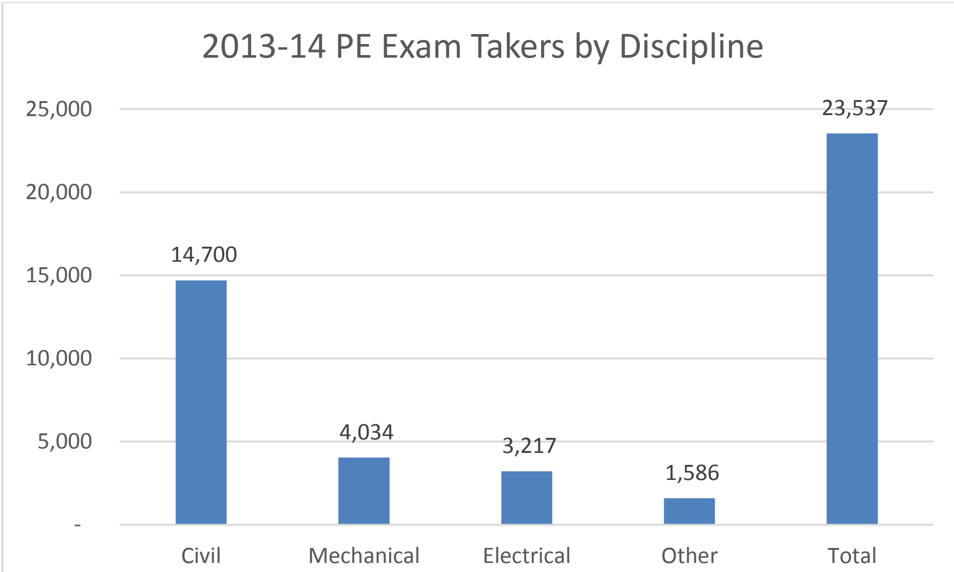

Figure 1 – Breakdown of overall takers of NCEES Principles and Practice of Engineering (PE) Exam by discipline.

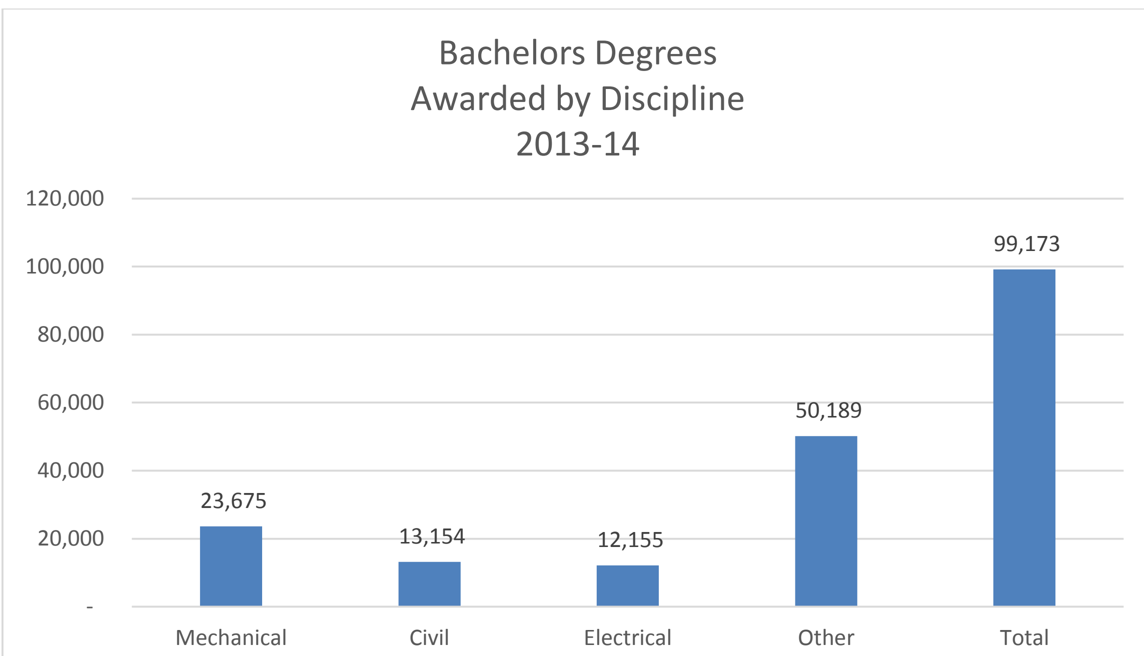

Figure 2 – Bachelor's Degrees Awarded by Discipline

With these facts as a foundation, the paper considers the benefit of graduate-level education to the engineer, their employer and society at large.

Does the engineer benefit from higher educational standards and can they earn return on the investment?

A recent Georgetown study reporting on median annual wages of college-educated workers (ages 25-59 in 2013 dollars) reported that the median annual wage for civil engineers with a bachelor's degree is $83,000, while the median wage for civil engineers with a graduate degree is $101,000, a 22 percent increase[9]. Table 1 provides data on the "earnings bump from a graduate degree" in a number of different engineering disciplines. The "earnings bump" ranges from 11-28 percent, depending on the engineering discipline.

Table 1
Engineering Master's Degrees Awarded in 2014

Engineering Discipline	Number Awarded[1]	% Earning Master's[2]	Earnings Increase[3]
Aerospace	1196	48.2%	24%
Architectural	not available	33.9%	13%
Architecture & Engineering	not available	38.2%	25%
Biomedical	1546	52.5%	24%
Chemical	1210	48.6%	14%
Civil	4478	36.5%	22%
Electrical	8746	42.5%	20%
Environmental	778	51.0%	16%
Industrial & Manufacturing	2456	40.1%	25%
Mechanical	5443	39.7%	23%
Metallurgical	863	54.4%	11%
All Other Majors	not available	35.2%	28%

[1]Source: Engineering Workforce Commission of AAES
[2]Source: The Economic Value of College Majors, Georgetown University
[3]Source: The Economic Value of College Majors, Georgetown University

Assuming a master's degree in engineering will cost $30,000-$40,000 on average and a non-thesis master's degree can be earned in one year, it's likely that the return on the investment can be as little as 4-5 years in many fields, as higher salaries correlate directly to a higher terminal degree.

Follow the market

What the market tells us is the best indicator of the tangible benefits of graduate-level education for civil engineers. Consumers will pursue what they feel is beneficial. Overall, the number of master's degrees awarded annually in engineering has more than doubled in the last thirty years as shown in Figure 3[10].

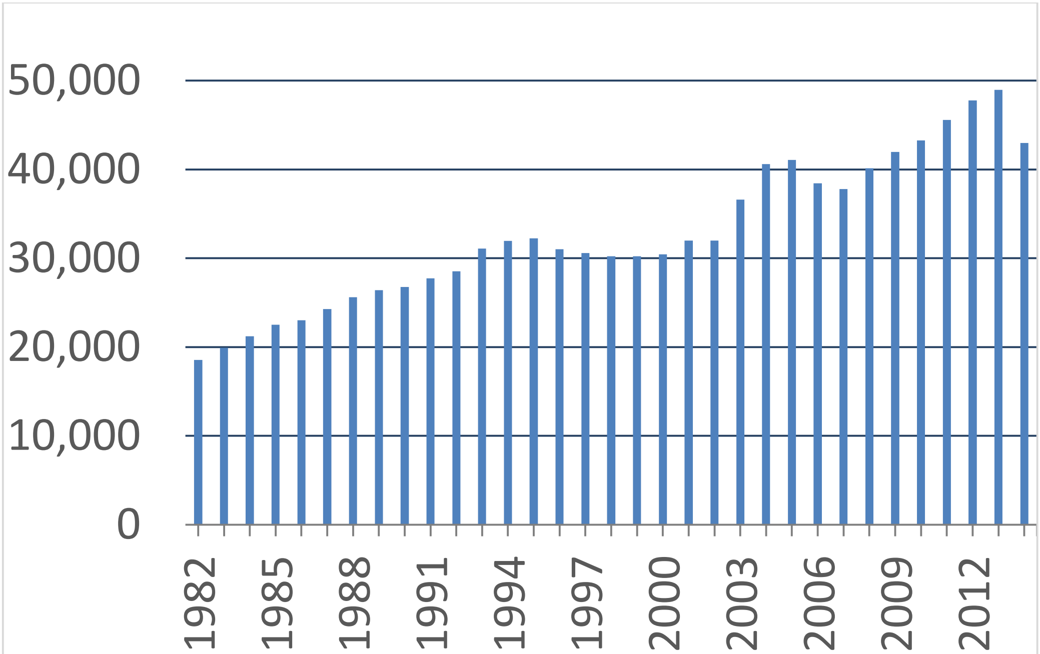

Figure 3. Master's degrees awarded in engineering – all disciplines (Source: Engineering Workforce Commission of the AAES)

The recent dip in degrees awarded can be attributed to the cyclical nature of engineering employment related to economic trends.

According to ASEE there were 14,226 bachelor's degrees and 6,447 master's degrees awarded in civil engineering in 2013-14 (including environmental and civil/environmental degrees – see Figure 4). This suggests that a significant percentage of these graduates go on to obtain an advanced engineering degree in civil or environmental engineering during their career, but these figures are also affected by international students. As the vast majority of civil engineers pursue licensure, it is logical to conclude that these individuals see the need, justification, and the value of a master's degree as they advance through their career as a PE. Figure 4 shows the breakdown of master's degrees awarded by discipline in 2013-14.

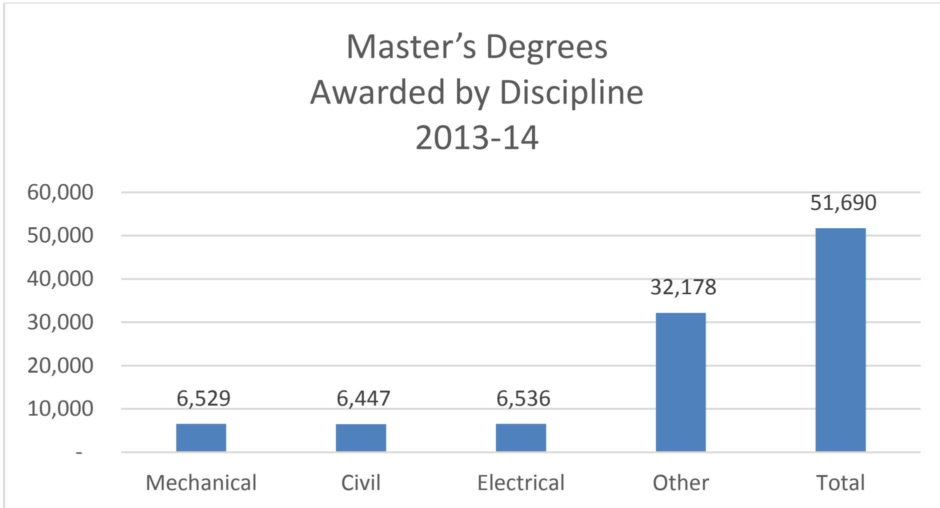

Figure 4 – Master's degrees awarded by discipline 2013-14 (Source: ASEE, 2015).

Another trend is the gradual increase in the ratio of master's to bachelor's degrees for domestic students as shown in Figure 5. The ratio has risen from 20 percent in the early 1980s to nearly 35 percent a number of times over the past two decades[11].

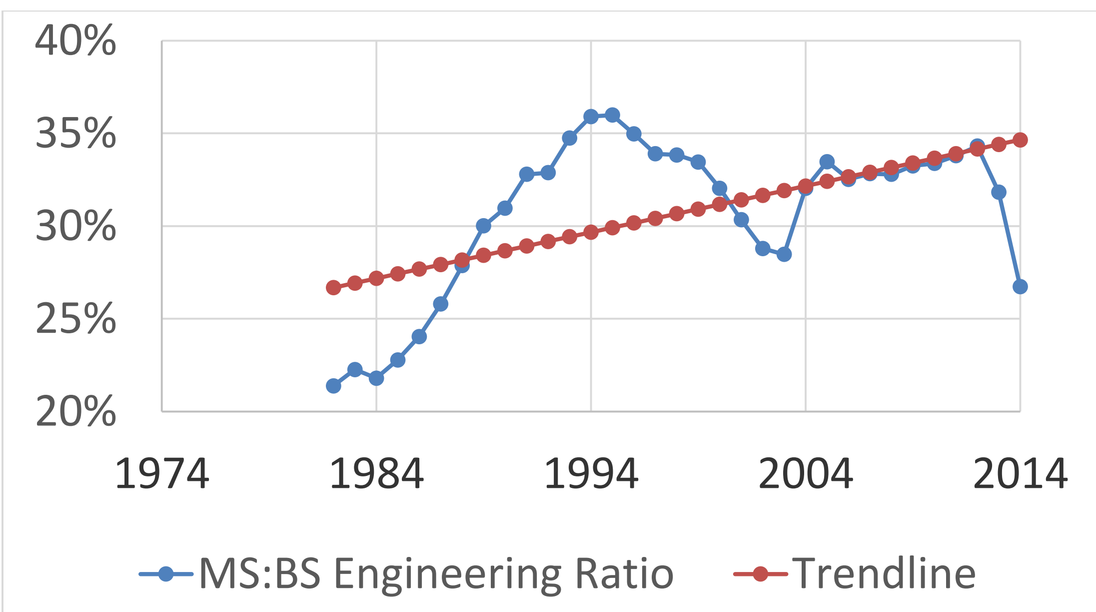

Figure 5. Ratio of master's degrees awarded in engineering to bachelor's degrees awarded in engineering – all disciplines for U.S. residents (Source: AAES, 2015)[11]

What do engineers gain with a Master's in Engineering?

ASCE in the Second Edition Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, published in 2008, described it best. The BOK contained 24 outcomes with specific levels of achievement from Bloom's taxonomy. They took the 24 outcomes and placed them into three categories: Foundational; Technical; and Professional. They further identified whether the outcome is chiefly fulfilled through the baccalaureate degree, graduate-level education or experience. A rubric that graphically depicts this work is included as Appendix A.

The BOK2 committee concluded that the baccalaureate degree provides a significant percentage of the foundational knowledge necessary to apply engineering principles. Engineers further develop their capabilities through work experience as they learn practical applications of their education. However, neither can provide adequate opportunities in the following key outcomes from the BOK:

> ***Experimentation*** *– Experimentation includes developing and conducting experiments, analyzing results and incorporating them into some practical application. This inquiry based learning emphasizes the method of discovery and analysis to develop the critical thinking skills necessary to learn in the experimental process. Critical thinking also helps develop engineering judgment, necessary in interpreting and analyzing results of experiments.*
>
> *The extent of specialized experimentation cannot be easily fulfilled within the baccalaureate degree. At the baccalaureate level, experimentation tends to back up the fundamental education being taught, but doesn't advance to higher and specialized experimentation, as the specialized education itself isn't contained in the baccalaureate program. Experimentation is a natural component of an advanced degree program, so more in-depth experimentation in a specialized field can be easily fulfilled.*
>
> ***Problem Recognition & Outcomes*** *– Civil engineering problem solving consists of identifying engineering problems, obtaining background knowledge, understanding existing requirements and/or constraints, articulating the problem through technical communication, formulating alternative solutions (both routine and creative) and recommending feasible solutions.*
>
> *The necessary levels of complexity of problem recognition and outcomes cannot be easily taught at the baccalaureate level. Similar to experimentation, there isn't enough depth in specialization to adequately explore and develop these skills at the baccalaureate level. Some of this skill set can be gained through experience, but it is also limited as employers are focused on efficient identification and resolution of problems. They don't have the luxury of allowing their young engineers to explore and develop these skills within the typical project team.*
>
> *Problem recognition and outcomes is a key component of an advanced degree program, as individuals explore the specialty area in much more detail than can be offered at the*

baccalaureate level. Better skills in problem recognition results in better solutions as the problem being solved is better defined and understood.

Technical Specialization *– Advanced technical education includes all traditionally defined areas of civil engineering practice, but also includes coherent combinations of these traditional areas in the context of advanced specialization.*

The baccalaureate degree program in civil engineering is often described as "a mile wide and an inch deep". This is not an indictment, but a simple reality of civil engineering education. Specializing at the baccalaureate level is not practical in many cases as the different sub-disciplines are so interrelated and basic knowledge in one is necessary to be competent in another.

With the ever-expanding technical knowledge needed to solve increasingly complex problems, technical specialization is necessary to stay abreast of new technologies and knowledge. Individuals cannot easily fulfill this through work experience. The academic setting is the most appropriate and efficient delivery model to fulfill this outcome.

This isn't a failure at the baccalaureate level

This is not an indictment of the civil engineering baccalaureate degree programs in engineering. Academics have done a remarkable job trying to fit an ever-expanding body of knowledge into traditional baccalaureate programs while program credit hours decline and there are justified demands to include more "soft skills training" within their already full programs. The civil engineering BOK concludes that the level of engineering knowledge needed by PEs to meet the ever-expanding and complex needs of our changing society cannot be taught solely within a four-year civil engineering program (see Appendix A). The breadth and depth of curricula needed simply doesn't fit!

With the ever-expanding complexity of societal needs and the techniques needed to address them, it should be obvious that post-baccalaureate education is necessary for all licensed professional civil engineers. In engineering as in other professions, a baccalaureate education can provide an engineer with the rudimentary knowledge of mathematical, scientific and engineering principles to complete standard calculations and respond to basic engineering questions. However, professional engineers, like other professional licensees are expected to do much more.

Better solutions

With graduate-level education comes greater maturity and leadership in approaches. Individuals become problem definers, not just problem solvers, which is essential to the project team. It is critical to first truly understand the problem before developing alternatives and solutions. Too frequently project teams develop a marginal response to a problem, because they failed to first truly understand the problem and solved what is only a tangential issue.

Theoretical versus practice-based master's

Civil engineers aspiring to practice in the academic and research environment are well served by the traditional Master of Science degree in civil engineering (MSCE) with its rigorous thesis option, but what about those seeking careers in industry, consulting, or agencies? In many universities the master's degree has evolved over the past few decades to enable a more practice oriented approach. Often, a three credit project or no project at all may be required in lieu of a thesis. Example programs with more of a practice-based programs of study include the University of New Mexico[12], Cal Poly Pomona[13], and Rensselaer Polytechnic Institute[14].

Pat Galloway, who served as ASCE President in 2004, envisioned a practice oriented degree in 2007[15]. She states:

> *"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. This master's program will provide engineers with the knowledge and skills now required of engineering professionals—specifically, an understanding of globalization; of the importance of ethics and professionalism; of how to work effectively with diverse, multinational teams; and of public policy."*

The development of high quality, practice-oriented engineering master's programs constitutes a major advance in engineering education. With these programs, an engineer can complete a master's degree while working full-time, in a two to four years, at costs comparable to a master's degree in residence at a university. Such programs are becoming more and more prevalent in civil engineering. Similar programs are less available in other engineering disciplines, but should expand as market forces call for them.

What about GPA requirements?

One frequent lament against increasing educational requirements for licensure is that many engineering graduates will not have a GPA upon graduation that will allow them entry into a master's program. This might be true for new graduates who want to immediately pursue graduate-level education, but a lower GPA would also suggest that they would be best served to gain some work experience before returning to school. With experience comes maturity and a better understanding of what they want to learn and why.

There are an increasing number of master's programs that look at these "less traditional" students favorably, as they consider their work experience along with their earlier academic performance and judge whether the student would succeed in their program or not. There are avenues for graduate-level education for those who didn't perform well enough to gain access immediately upon graduation.

It should also be pointed out that engineering graduates with a baccalaureate degree must attain a minimum of four years of progressive engineering experience after graduation (in most states), before they can sit for the licensure exam, so there is no need to immediately enter into a master's program upon graduation. Some engineers will want to have time to gain work experience and better understand where they want to focus when they pursue graduate-level education.

What does the market tell us?

Probably the best metric to determine whether a master's degree is important to today's engineering graduates is the number of engineers who pursue graduate degrees. As shown in Figures 3, 4 and 5, more than a third of all civil engineers and nearly half of environmental engineers pursue an advanced degree at some point in their career.

Engineers see the need for graduate-level education to gain the knowledge required to do what they want to do in their career, as well as the advancement and salary increases that come with a graduate degree. Engineers with graduate-level education are much more capable to practice in our ever more complex world. The 21^{st} century engineer is recognizing this at an ever-increasing rate.

Does the employer benefit from higher educational standards?

C.R. "Chuck" Pennoni founded a consulting engineering firm bearing his name in 1966, now celebrating its 50^{th} anniversary, with more than 1,200 employees. In addition to growing his firm to match the needs of an expanding client base, Chuck has also served the profession as a member of the Pennsylvania Registration Board for Professional Engineers, Geologists and Surveyors from 1988- 1991; President of the American Society of Civil Engineers in 1991-92, as President of ABET, the accrediting body, in 1998-99; and as President Emeritus of Drexel University, having served twice as Interim President, from 1994-95 and 2009-10. Chuck was an original supporter of a master's degree as the first professional degree required for licensing as a Professional Engineer. In Chuck's words:

> *"The matter of a master's degree as the entry level for a Professional Engineer is long overdue. The body of knowledge has increased significantly over recent decades, while the required length of study to attain a bachelor's degree has decreased. Professional Engineers must decide between a profession (a specialty, a calling) and a commodity (merchandise, goods). Licensing in and of itself does not make for a professional. For example, trades are licensed. Not only is the additional education necessary to provide quality engineering but also to elevate the "profession" to a level comparable to other professionals."*

In larger firms like Pennoni, many new hires, particularly in specialty fields, have master's degrees as they enter the firm. Some firms in specialty practices only hire master's candidates. Others embark on a master's program, supported by the company early in their career. In pursuit of the master's some focus heavily on graduate-level technical coursework, while others pursue a program with similar high-level engineering management offerings. Both prepare budding professionals with the requisite skills to serve the public – developing, advancing, and promoting sound engineering practice.

As employer size grows, along with project complexity, many diverse skills and talents are necessary to round out engineering teams. Not only are the skills technically diverse, but the team needs different levels of experience and credentials necessary to be well-rounded and efficient. The PE in responsible charge has management and leadership skills beyond strict technical capabilities. They manage both the overall project and lead others with specific technical expertise, and communicate with the various publics to explain, obtain input on, and "sell" an engineering idea.

Other team members offer the needed level of competence to effectively complete their assigned tasks. These staff include fellow PE's, graduate engineers, technicians and other support roles. There may also be PE "experts" in a given area of practice. They might have knowledge more advanced than the team leader, which allow them to identify more advanced solutions, but frequently these "experts", lack the management skills to be in responsible charge of the work by themselves. The project team leverages the strengths of each individual team member to complement each member's efforts into a comprehensive, technically sound, and efficient delivery of services.

Engineers with graduate-level education are typically granted more freedom to practice and are put in responsible charge quicker than those with lesser degrees as their education has provided a broader base of knowledge that can only otherwise be obtained through time on the job, gaining experience as they are gradually introduced to more complex work as their employer determines they are capable. Employers recognize the ability of their engineers with graduate-level degrees to perform at a "higher level", which is ultimately why salaries are higher for engineers with advanced degrees. If employers didn't see the value, they would not pay a premium

Employers will invest in graduate-level education

It is common for engineering firms of all sizes to offer some form of tuition reimbursement as an investment in select employees who want to pursue graduate-level education. In many cases, tuition costs are split with the employee so employees "have some skin in the game". There may also be a commitment by the employee to stay with the employer or reimburse them for employer costs if the employee leaves the firm before a set period of time. The employer gains a more educated and qualified employee who has pledged their loyalty to the firm, because of the investment that the employer made. The return on investment to the employer is obvious as they invest in the right individuals and empower them to use what they learned to deliver higher quality services.

Good managers and company leaders can quickly identify those individuals who warrant the investment. Management can assess their eagerness and willingness to pursue graduate-level education to fulfill their desire to understand and master an area of practice of civil engineering necessary to practice competently. Others might not rise to the same level, not willing to invest the time and energy (nor frankly be competent enough) to pursue graduate-level education. These individuals are not "out of luck". There are roles for graduate engineers who don't wish to pursue licensure in every firm. They don't advance to responsible charge of the work, but they can remain a key part of the project team.

Brad Aldrich, founding partner in a smaller firm (20-25 employees) for the past twenty years, has seen the difference in the abilities, initiative and competency of the firm's engineers based on their level of education. The firm accepts its obligation to provide new engineering graduates with the broad and detailed experience that they will need to competently practice as a professional engineer. These graduates are prepared for professional practice by exposing them to all the experiential outcomes needed to competently practice, but firms of most any size are neither prepared nor capable of identifying and fulfilling fundamental and specialized engineering education needs that might be lacking in their pathway to licensure.

Aldrich cites an example of one employee who had a rather untraditional and circuitous route through his baccalaureate education, completing his degree in six years. His GPA qualified him for graduation, but not graduate school. Upon graduation he joined the firm and exhibited growth in aptitude and attitude over the next ten years. He approached firm leaders to support his desire to pursue a master's degree while holding down a full-time job and supporting a family. Management jumped at the chance, quickly recognizing the return they would receive on the investment.

This individual was accepted into a highly regarded on-line and in-person master's program after admissions reviewed both his academic credentials, his work experience, and the maturity that he had demonstrated in his work that would correlate to successful completion of the program. They were not interested in simply filling seats with anyone who wanted to sign up. Just like employers, institutions of higher learning are motivated to succeed. He excelled in the program, is a much more competent engineer, and loyal to the firm, because the firm was loyal to him. He has become a key employee who is already assuming senior leadership roles. The investment was "a no-brainer" and the firm is reaping dividends for its investment.

Project team of the future

Traditional engineering practice has emphasized the need for every engineering graduate to gain the necessary experience and knowledge required to become licensed. The focus has been "get licensed or get out". As firms re-think what licensure means in an ever-more complex society, they will recognize that they don't need more PEs as much as they need better (more competent) PEs. It's also time for engineering firms to re-think how they deliver engineering services. They need to follow the lead of other comparable licensed professions who have evolved to best meet societal demands in the most efficient and effective way.

In medicine today, you typically see your physician for less and less time, while nurse practitioners, physician's assistants, and other medical professionals perform the basic investigative work to assess your health. The doctor is free to focus on the results of these tests, consider patient history, and draw conclusions about the patient's health needs, removed from the distraction of the more mundane activities that can be competently provided by technicians and other medical professionals with lesser qualifications. The patient receives a higher level of service and more comprehensive care as the licensed professional is freed to do what only they can do, while trained personnel support the professional's efforts. Dentistry and accountancy are evolving to a similar model, where the licensed professional can spend more time analyzing the data, identifying problems and the best solutions to address them, free from the tasks that can be competently performed by others.

Engineering needs to embrace a similar model. The PE in responsible charge should be free to better identify and define the problem, and guide the project team. They should be free to better understand and interpret the data, review the alternatives, select and develop the best one given all the facts before them. This will result in better problem identification and understanding, and better solutions. Other professions have demonstrated that this model is efficient, successful and serves society well.

PEs with graduate-level education will be more productive and efficient as they can focus on the problem and not be distracted by the simpler tasks needed to evaluate alternatives. They are able to monitor and support more project teams and address more problems (similar to other professions), because of this freedom. The quality of engineering improves and organizations see efficiencies and better solutions. This is clearly in the best interest of employers and consumers.

Does society as a whole benefit from higher educational standards?

Engineering is the creative and innovative application of mathematical, scientific and engineering principles to solve both practical and complex problems facing society. Theodore Van Karman said it best: *"Scientists discover the world that exists; engineers create the world that never was."* [16]

Professional engineers are charged with applying their knowledge to address societal needs that become more and more complex as sustainability, environmental, social and other global factors must now be taken much more into account. It becomes exponentially harder each passing year to know all the advances in any given area of practice necessary to meet these evolving societal demands. Advanced and specialized education provides the licensee with more specific comprehension and knowledge of an area of practice, that allows them to stay current and on pace to meet these ever-expanding demands. The professional engineer is better able to view the bigger picture and is better at identifying and understanding the problems they are facing as their knowledge and experience is substantially more attuned to the more complex principles that are required to provide innovative engineering solutions. Ultimately, this results in higher quality services (a rising standard of care) at more competitive fees as economies are realized with more expansive knowledge lending to more efficiency in the completion of the services.

As the old saying goes…"*a rising tide floats all boats*". Similarly, a rising educational standard benefits society. More competency leads to more creative and innovative engineering work. Society benefits in many ways, including more creative and economical solutions that better address new societal pressures such as sustainability, socio-economic impacts and other social and environmental considerations.

Society demands more of their licensed professionals

Since licensure was first adopted in Wyoming in 1907, states have relied upon the bachelor's degree in engineering as the minimum level of education for licensure as a professional engineer. In 2016, the bachelor's degree remains the traditional minimum education standard for licensure as a PE, while comparable licensed professions have recognized that society is best served by licensees that have specialized, post-baccalaureate education, as shown in Figure 3[17].

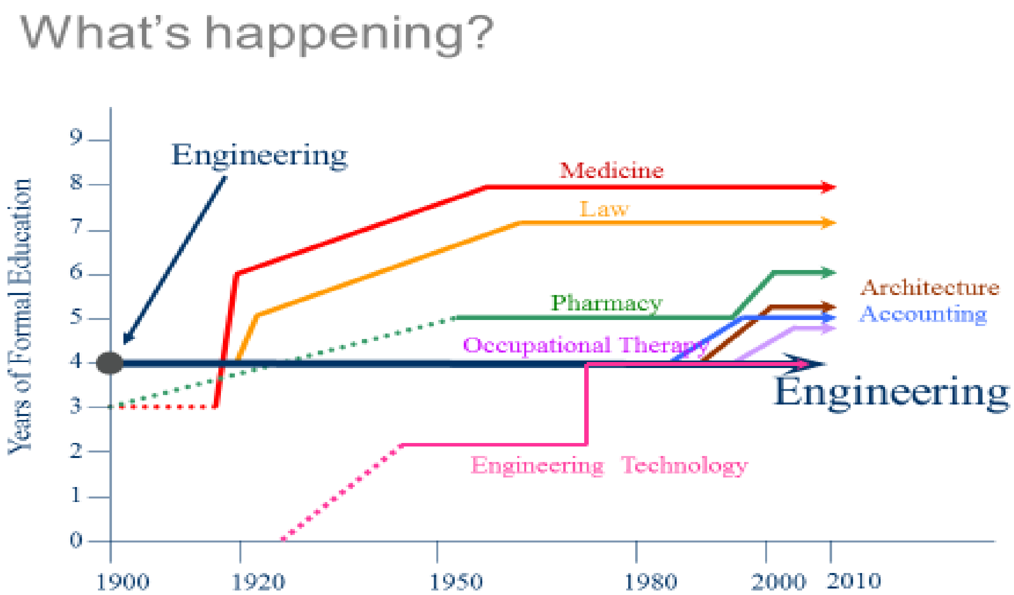

Figure 3 – A Leader No Longer.

The medical, pharmacy, legal, architecture and accountancy fields all require post-baccalaureate education to obtain a license. Other professions such as physical therapy and occupational therapy are moving to the same standard. Even engineering technology, which traditionally was a two-year degree program covering basic engineering training to perform simple technical tasks in support of the project team has evolved to a four-year degree.

In most cases, it was society that demanded a higher standard. One recent example is accountancy. With the high profile failures of Enron, WorldCom, and other large corporations accused of fraudulently reporting economic performance to bolster their "bottom line" to stockholders, society demanded better of the certified public accountants (CPAs) who were charged with ensuring that financial reports were accurate and not misleading to investors. Fallout from these scandals prompted the fall of some of the largest accounting firms in the nation, for their failure to protect the public's interests.

In 1988, the American Institute of Certified Public Accountants (AICPA) adopted a proposal to require all new accountants after the year 2000 to have completed 150 semester credit hours of college education to sit for the CPA exam[18]. Since most baccalaureate programs in accountancy included approximately 120 semester credits for graduation, those seeking a CPA license (post 2000) would need to seek out an additional 30 semester credit hours before they could sit for the CPA exam. In the subsequent years, most but not all fifty states and territorial jurisdictions have adopted this standard. Over time upon adoption, the number of takers and pass rates for those taking the CPA exam have risen.

There are a lot of similar compelling arguments to require a master's degree or similar education for licensure as a professional engineer. Gone are the days when engineers can apply relatively basic mathematical, scientific and engineering principles to develop an engineering solution to one of society's problems. The complexity of societal needs and commensurate engineering knowledge and expertise needed to meet them expands at an exponential rate as each year passes and our understanding of our world grows. The PE's competency must increase at a similar rate, if they are to meet their duty to society.

A leader no longer

The U.S. was a world leader in implementing licensure of professional engineers for much of the first half of the 20th century. From its initiation in 1907 through its established in all 50 states by 1947[19], the U.S. licensure system was considered the "gold standard" internationally. Today there are European and South American countries that have longer engineering educational programs than the U.S. For example, an engineer in Ireland or Great Britain must earn a master's degree or equivalent after completing a bachelor's degree to obtain chartered status. Colombia and Peru have five year undergraduate programs. As more countries raise the bar on their educational standards, a U.S. PE license may no longer be readily accepted in other countries for purposes of responsible charge.

ASCE, in their second edition of the Engineering Body of Knowledge for the 21st Century Engineer (published in 2008) summarized the needed changes in the opening sentences of their Executive Summary:

> *"The manner in which civil engineering is practiced must change. The change is necessitated by such forces as globalization, sustainability requirements, emerging technology, and increased complexity with the corresponding need to identify, define, and solve problems at the boundaries of traditional disciplines."*

The publication goes on to identify three critical outcomes where a master's is necessary to achieve competence:

- *Ability to achieve synthesis in experiments;*
- *Ability achieve analysis in problem recognition and solving; and*
- *Ability to achieve comprehension, application, analysis, and synthesis in one's technical specialization.*

The National Society of Professional Engineers (NSPE) created the NSPE Body of Knowledge[20] designed as a guiding document for all engineering disciplines. Similar to the ASCE BOK, NSPE identified 30 capabilities (outcomes) that an engineer should master prior to licensure. Recognizing that this path can vary among disciplines and individuals, NSPE concluded:

> *"Each capability is usually acquired through a combination of engineering education and experience. NSPE will not attempt to "tease apart" what aspects or parts of capabilities are fulfilled through education or experience, because these means may vary significantly across disciplines and employment circumstances."*

Is promoting graduate-level education in the national interest?

The American Society for Engineering Education (ASEE) recently reported on a disturbing trend[21]. Today more than 63 percent of graduate students enrolled in engineering programs are foreign nationals (excluding U.S. Resident Aliens). In 2005 the percentage was half that. Perhaps if more American students pursued additional studies, including a master's degree, the domestic research enterprise in engineering could be strengthened and America could continue to maintain a competitive advantage in the development of new engineering technologies. Currently there is heavy dependence on recruiting top educated talent from abroad. In the same article engineering luminary Norm Augustine states:

> *"The ratio of U.S. to international graduate students should be even more of a worry than when the panel published its follow-up report in 2010."*

The report went on to say:

> *"The comparative underrepresentation of United States citizens studying the natural sciences and engineering, particularly at the doctoral level, is of particular concern."*

Reviewing the number of graduate degrees awarded in civil engineering from the report, 30 percent of all master's degrees and 59 percent of all doctoral degrees were awarded to foreign nationals in 2014.

Conclusions and Next Steps

The vision for the future of the civil engineer profession on a global scale is enunciated in the publication The Vision for Civil Engineering in 2025[22], which imagines a future 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."*

There are many compelling arguments to require post-baccalaureate education for licensure as a civil engineer. Not the least of which is:

- A demonstrated benefit to the engineer who attains it
- A demonstrated benefit to the employer to hires them
- A demonstrated benefit to society

The market tells us that graduate-level education is good for engineering. Engineers are pursuing graduate-level education at an ever-increasing rate. They recognize the benefit in their career advancement and their ability to delve into problems with a much better understanding of the principles needed to make informed and innovative decisions. The market also tells us that employers recognize the value as they are willing to pay engineers with graduate-level education higher wages commensurate to that education. Employers would not do this unless they saw the direct benefit to the organization.

Ultimately, society benefits as engineers have higher competency, which lends itself to a better problem identification and better understanding of all the factors that influence the problem at hand. Engineers do a better job of correctly identifying and understanding the problem and consequently do a better job applying innovation to identify an alternative that will result in an adequate solution. Lastly, every other comparable profession has recognized the need for graduate-level education and society has embraced it. Why should engineers think they are different?

The Raise the Bar Committee of the American Society of Civil Engineers and the authors continue to maintain a strong interest in developing a more quantifiable business case for advancing the educational requirements for licensure and plan to continue to research and publish on the topic. They encourage the Raise the Bar Committee to pursue data collection efforts that might further enhance the business case for raising the bar.

Note that the views and opinions expressed in this paper are the authors' and do not necessarily reflect ASCE or company policy.

APPENDIX A

ASCE'S BOK RUBRIC (ASCE, 2008)

Outcome Number and Title	*Level of Achievement*					
	1 Knowledge	*2 Compre-hension*	*3 Application*	*4 Analysis*	*5 Synthesis*	*6 Evaluation*
Foundational						
1. Mathematics	B	B	B			
2. Natural sciences	B	B	B			
3. Humanities	B	B	B			
4. Social sciences	B	B	B			
Technical						
5. Materials science	B	B	B			
6. Mechanics	B	B	B	B		
7. Experiments	B	B	B	B	M/30	
8. Problem recognition and solving	B	B	B	M/30		
9. Design	B	B	B	B	B	E
10. Sustainability	B	B	B	E		
11. Contemp. issues & hist. perspectives	B	B	B	E		
12. Risk and uncertainty	B	B	B	E		
13. Project management	B	B	B	E		
14. Breadth in civil engineering areas	B	B	B	B		
15. Technical specialization	B	M/30	M/30	M/30	M/30	E
Professional						
16. Communication	B	B	B	B	E	
17. Public policy	B	B	E			
18. Business and public administration	B	B	E			
19. Globalization	B	B	B	E		
20. Leadership	B	B	B	E		
21. Teamwork	B	B	B	E		
22. Attitudes	B	B	E			
23. Lifelong learning	B	B	B	E	E	
24. Professional and ethical responsibility	B	B	B	B	E	E

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

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