

## **2006-1110: THE CIVIL ENGINEERING FACULTY OF THE FUTURE**

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# **The Civil Engineering Faculty of the Future**

## **Abstract**

The American Society of Civil Engineers (ASCE) has published the Civil Engineering Body of Knowledge (BOK) for the 21<sup>st</sup> Century that attempts to define the knowledge, skills and attitudes required of a civil engineer. A section of that document addresses who should teach this body of knowledge. It concludes that civil engineering faculty must be scholars, effective teachers, practitioners, and role models. While true, there are a number of complex issues that arise such as whether it is possible for one person to possess all of these attributes, whether such a model best serves the projected trends in civil engineering education, and whether these needs are applicable to and can be enforced for non-traditional, non-university civil engineering programs. As a new committee (BOK-2) has formed to write the second edition of this document, the ASCE Committee on Faculty Development is revising the “who should teach” chapter for this effort. This paper discusses some key issues that are relevant to the civil engineering faculty of the future.

## **I. Introduction**

Through the formal development of Policy 465, the American Society of Civil Engineers has defined the Body of Knowledge (BOK) that describes the knowledge, skills and attitudes necessary to become a licensed professional engineer<sup>1,2</sup>. The BOK is presented in the form of 15 outcomes that prescribe the necessary breadth and depth of knowledge required for a practicing civil engineer. The levels of competence for these outcomes were initially defined as recognition, understanding, and ability, but have recently been revised to be defined using the six levels of Bloom’s Taxonomy<sup>3</sup>. The attainment of the BOK is expected to occur through a broad undergraduate education, specialized education at the masters level, and practical experience during the pre-licensure and post-licensure periods.

One of the next crucial issues associated with this initiative to raise the bar in civil engineering education is, “Who should teach the BOK?” Currently, the model is that all tenured faculty must have a Ph.D. and if they are teaching a design course, they need a professional license or equivalent education and experience. It is extremely difficult to find a faculty member who is an outstanding researcher, has extensive academic credentials, and possesses experience in professional practice. What is the ideal combination? Must the person teaching design have more than just the minimum number of years of practical experience necessary to sit for the PE? Or should these faculty have additional years of design experience and continue to work as consultants in their chosen sub-disciplines so they can bring those day to day experiences into the classroom? Some schools have moved to this model, but will only provide lecturer or Adjunct status to these faculty. What message is being sent, especially if tenure is only offered to those with a Ph.D.? Which faculty are more valuable -- those that can teach the required design in each program and can bring in dollars through consulting or those bringing in research dollars? Tenure is already under attack at many schools and more schools are bringing in Adjunct faculty to provide the necessary skills they currently lack in their faculty. As industry asks for engineers who can communicate, should there be a technical writer as a member of the

faculty? As programs become increasingly multi-disciplinary, to what extent should faculty positions be shared appointments between departments? This option is increasingly important as the newest BOK outcomes focus on public policy, leadership and management, all of which are topics traditionally taught outside an engineering program.

The ASCE Body of Knowledge<sup>1</sup> contains a chapter written by the ASCE Committee on Faculty Development (CFD) that considers “Who should teach the BOK?” The purpose of this paper is to summarize that chapter, discuss options, and examine recommendations for changes to the current traditional faculty model used by most institutions. As the civil engineering profession attempts to raise the bar on the education required for a professional engineer, it is also time to consider what the ideal faculty of the future should look like and “Who should teach the BOK?” There is no complete answer, but changes will be required and now is the time to begin the discussion.

## **II. Summary of Existing BOK Chapter on “Who Should Teach It?”**

The “Who Should Teach It?” chapter of the BOK states that there are four characteristics needed from full or part time civil engineering faculty. They need to be scholars, effective teachers, practitioners, and role models. The scholarship may include scholarship of teaching, discovery, integration or application as defined by Boyer<sup>4</sup>, but the important attribute is that scholars are life-long learners who are continually gaining and applying new knowledge. Because student learning is directly tied to effective teaching, the ability and willingness to be an outstanding classroom teacher remains important. Effective teaching is defined in terms of Lowman’s two-dimensional model of intellectual excitement and interpersonal rapport<sup>5</sup> and the ExCEED Teaching Model<sup>6</sup>. Because civil engineering education for many students is preparation for professional licensure and a career in civil engineering practice, those who teach it should have practical experience as an employed engineer in a consulting firm, industry or a government agency. How can one effectively teach what they have never done themselves? Finally, the faculty need to display the same attitudes, knowledge, behavior and skills required of a civil engineer. Students need to see role models that they can emulate as they enter the civil engineering profession.

Since early 2004 when the BOK was published, the ASCE Committee on Academic Prerequisites for Licensure and Professional Practice (CAP3) and its constituent sub-committees have received considerable input and feedback on the document and the raise the bar initiative in general. In November 2005, the Second Edition of the Body of Knowledge Committee (BOK-2) was formed to rewrite the BOK. The ASCE CFD is currently revising the “Who should teach the BOK?” chapter. The current draft lists the same four characteristics required of faculty members as the original and adds a section on the obligations of the ideal educational institution. This institution will hire the faculty and will determine the rules for successful performance. The institution therefore has some obligations to the faculty, the students and the profession<sup>7</sup>. The commitment and priorities of the university will in many cases dictate the quality, the priorities and the performance of the faculty.

By the committee’s own admission, this chapter is still incomplete. Deficiencies that the committee has identified include:

- If an individual faculty member needed to be complete in the areas of scholarship, effective teaching, professional practice and being a role model, a majority would not measure up. It is too hard and the requirements to be successful and accomplished require more time and effort than one person possesses. While every faculty member should be a role model, most faculty members are outstanding in one of the remaining three areas and merely adequate in the other two. Perhaps that should be the standard.
- The current entry path into the tenure track university faculty position requires a Ph.D. This chapter does not offer a good way to bring an experienced practitioner into the academic environment.
- The discussion to date has focused on the traditional classroom teacher. Non-traditional means of education through web-based instruction, distance learning, virtual universities or professional development courses will be providing elements of the Body of Knowledge. Do the characteristics required of the traditional faculty apply in non-traditional situations?
- The theme of the BOK is to expand the breadth of the undergraduate experience away from pure technical content, while gaining skills in communication, leadership, management, professional responsibility and public policy. Since this is not the area of expertise of many current CE faculty, who should teach these subjects? Do current faculty need to expand their education or are new hires needed?

This paper addresses some of these issues and offers some possible suggestions. The answers will not come without further study and input from others. It is important now to properly frame the question and explore the available options.

### **III. Current Situation**

Civil Engineering is a profession with a distinguished history of service to the nation and most people have a good idea of what a traditional civil engineering program looks like. Civil engineers have long been in the business of designing, constructing and managing infrastructure. The sub disciplines are well defined and fall into the areas such as structures, geotechnical, water resources, environmental, construction management, and transportation. While civil engineering programs may focus on the sub disciplines to varying degrees, most programs are fairly predictable. One can expect to see some engineering science in the form of statics, dynamics, fluid mechanics, thermodynamics and mechanics of materials followed by an assortment of required and elective engineering courses in such areas as concrete design, foundations, surveying, road design, hydraulics, and project management. The accreditation requirements and licensing exams ensure that the civil engineering programs contain certain common requirements.

Some consider the current system necessary and beneficial. It ensures that society is protected and that those who are designing our buildings and bridges have had the education to do so competently. The accreditation process is a self-policing function that protects the high quality of civil engineering programs around the country. Others find this system to be stifling, inflexible and too prescriptive. As state legislatures have forced civil engineering programs to fit into 120 or 128 credit hour programs, there is little room for creativity or innovation after all of the mandatory requirements have been met. As technology has expanded, engineering has

become more interdisciplinary and the expertise required goes far beyond the traditional civil engineering sub-disciplines. The cutting edge areas of research are not in reinforced concrete, channel flow, or traffic design. They are in biotechnology, nanotechnology and information technology. To be successful in those areas, civil engineers need to partner with other disciplines and be released from the shackles of traditional civil engineering program constraints. The Body of Knowledge committees find themselves in the center of the competing viewpoints, both which have valid concerns. These issues intimately involve the hiring and promotion of the faculty.

The Civil and Environmental Engineering Program at Carnegie Mellon University is pursuing research in a number of non-traditional areas. Research in biology includes remediation with microbes, construction materials, alternative fuels, and sensors. Other research includes computational engineering, process re-engineering, ubiquitous intelligence and sensing, and remediation with nanoparticles. Carnegie-Mellon's strategy for acquiring the new skills to accommodate this research includes hiring faculty in CE with new backgrounds and skills, partnering with appropriate methodology/technology groups, re-training existing faculty, and broadening educational opportunities or requirements for CE students. Success relies on increased flexibility. Their progress is already measured in terms of a third of their faculty are joint appointments, two-thirds of their peer-reviewed publications are with authors from outside the department and all doctoral committees have outside members.<sup>8</sup>

Michigan State University is also focusing on non-traditional areas of research and finds some of the current requirements for faculty to be counterproductive. Examples of their most productive research includes parallel microbial detection using gene chips, self powered wireless sensors for infrastructure, biomaterials for structural applications, and coupled biological-chemical-physical transport of contaminants over large scales. The faculty members that they hire to conduct this research are not driven to obtain a professional engineering license. They are not particularly qualified to teach practice-oriented classes such as surveying, leadership, or traditional engineering design.<sup>9</sup>

Other universities such as University of Illinois, California Berkeley, University of Minnesota, Georgia Tech, M.I.T., Northwestern, University of Michigan, Stanford, University of Wisconsin and University of Texas-Austin have similar concerns and have expanded the breadth of research in their civil engineering programs. They are finding that even the traditional subdisciplines of civil engineering are being realigned into interdisciplinary areas such as environmental biotechnology, sensors and sensor networks, hydrological/ecological interactions, geoenvironmental engineering, multi-scale analysis, multi-hazard mitigation, and computer integrated construction.<sup>10</sup>

The Engineer of 2020 study<sup>11</sup> supports this line of reasoning when it states the world will be intensely interconnected and technological problems will be both interconnected and interdisciplinary. The study predicts that technology and engineering knowledge will grow most in the areas of bioengineering, biotechnology, biomedical engineering, nanotechnology, information technology, and large scale systems integration. While it appears that civil engineers need to expand their technical expertise beyond the traditional sub-disciplines, the study also declares that engineers need a stronger sense of how technology and public policy

interact and should be prepared to take a leadership role in political decision making. The attributes required of the engineer of 2020 include strong analytical skills, practical ingenuity, creativity, communications skills, business and management skills, leadership abilities, and high ethical standards. The new breed of engineer will need to be dynamic, flexible, agile, and able to learn new concepts. With increased globalization, changing technology, and new challenges, it is more important that engineers learn how to learn and continue the practice over a lifetime. The study concludes that the implications for education include teaching engineering early, integrating math and science with engineering, minimizing a required core of courses, featuring electives in non-technical subjects, defining breadth in terms of thought processes to facilitate learning how to learn, moving from a sequential to a holistic curriculum, and recognizing that the fundamental courses may change as technology evolves. With these additional requirements a four year engineering degree may no longer be sufficient and a master's degree may be required. The ASCE Task Committee on the First Professional Degree reached this same conclusion after benchmarking the educational requirements and starting salaries of the civil engineering profession with those of lawyers, doctors, accountants, architects, and other engineers<sup>12</sup>.

The Body of Knowledge supports these conclusions by attempting to broaden the skills and attributes of engineers. In addition to the outcomes listed in the ABET 3 a-k criterion<sup>13</sup>, the BOK requires four new outcomes, three of which respond to the need for engineers to broaden their abilities outside of technical fields

- Ability to apply knowledge in a specialized area related to civil engineering
- Understanding of the elements of project management, construction, and asset management
- Understanding of business and public policy and administration fundamentals
- Understanding of the role of the leader and leadership principles and attitudes

The ASCE effort supports the concept that an engineering bachelor's degree is not sufficient. The undergraduate education can focus more on developing a well rounded engineer and some of the more specific technical content can be included in the master's degree or equivalent post-baccalaureate education.

#### **IV. Who Should Teach the BOK**

One approach to determining who should teach the Body of Knowledge is to list the 15 outcomes that comprise this body and assess who is best qualified to teach each outcome separately. Table 1 represents such an attempt. For each BOK outcome, the authors considered four categories of faculty members: 1) the traditional faculty member with Ph.D. who has significant research responsibilities and interests; 2) the faculty member with at least a masters degree in the civil engineering discipline but no significant practical industry or research experience; 3) the faculty member with only a masters degree, but has at least 15 years of relevant experience as a practicing civil engineer; and 4) the faculty member with educational expertise in a discipline other than civil engineering. The bold **xx** indicates that this person is best qualified to teach a particular outcome; a single **x** indicates that the person is qualified; and a blank cell indicates that the person is probably unqualified to teach material associated with that outcome.

While the choice of ratings is preliminary and subject to debate, some simple conclusions can be drawn. It appears that the researcher, practitioner, and faculty member from other disciplines are all uniquely qualified to teach specific elements of the BOK. All are needed on the faculty of the future. In addition, there are numerous elements of the BOK that can be adequately taught by a faculty member without either significant research or industry experience. The challenge will be to have all of these groups represented on the faculty of the future, use them in the most appropriate manner, and reward them accordingly.

## **V. Faculty Issues**

As the requirements for practicing engineers become greater and the scope of what constitutes civil engineering expands, the traditional model for faculty recruitment and promotion will have to change as well. Some issues that arise from this include:

- It may very well be impossible for a faculty member to possess the attributes of being outstanding researchers, teachers, and practitioner. Felder<sup>14</sup> contends that traits, actions and priorities that make one a great researcher may be at odds with what makes a great teacher. Perhaps, it is sufficient to require that the civil engineering faculty as a whole possess these attributes. While some states such as Idaho require all civil engineering faculty to be professionally licensed, the ABET/ASCE Civil Engineering program criteria only require that those faculty that teach design courses to be licensed or demonstrate equivalent educational and design experience. Similarly, the standard of the future might be that only those who are conducting research need to have a Ph.D. Perhaps, a CE faculty only needs to have one or two experts in technical writing or business policy if it can be shown that those individuals are providing the appropriate oversight and evaluation of course content. It will still be necessary for all those who appear in a classroom to be both role models and competent teachers.

- As the civil engineering discipline becomes more interdisciplinary, perhaps the faculty composition needs to become more interdisciplinary as well. As the number of faculty in any department will naturally be limited and can only accommodate a fixed number of specialties, the case for more shared appointments becomes more compelling. The arguments in favor of joint appointments include more communication between departments, a wider sharing of needed expertise, and an efficiency that allows a wider variety of specialized technical expertise at a single university. A jointly appointed faculty member will know the capabilities and personalities of the professors in both departments and can act as a liaison between the departments and a catalyst for collaboration. This works in a collegial and cooperative atmosphere. Such appointments can be disastrous in a more dysfunctional environment where the jointly appointed faculty member is serving two masters with different and competing visions. If the faculty member is competing for tenure, then the situation can become unbearable. Perhaps, the solution is broader and academic departments may have outlived their usefulness. Academic departments have served universities well as a means of managing resources, research and expertise when engineering disciplines were defined along clear boundaries. As interdisciplinary expertise increasingly crosses these boundaries, it may be concluded that academic departments are too parochial

and actually hinder the sharing of expertise and information needed for further technological advancement.

- As long as civil engineering remains a profession that many students will join upon graduation, members of the industry are needed in the classroom. As students are increasingly required to understand the professional responsibilities facing engineers, the ethical and business considerations of an engineering effort, and the social, economic and political implications of engineering projects, practitioners who have experienced the industry first hand will be needed to teach these subjects. Only a person who has worked on a real world engineering project is best qualified to assess whether a student capstone design project is realistic and relevant. If practitioners are needed, then there needs to be a career track where their services can be valued and rewarded. Practitioners are typically included on the faculty as adjunct professors. They are paid less and not viewed as full-fledged partners. Most do not have the Ph.D. credential that accords equal status. The advantage of this system is that the practitioner faculty member is typically teaching as a side job, while he is working in a firm as a primary job and continues to stay current in professional practice and can bring those experiences into the classroom. Nevertheless, there should be some path to success for a practitioner who wants to make teaching students his first priority. For many schools this is a business decision. Research funds the universities and those who bring in those dollars should be rewarded appropriately. Perhaps a similar model can be established where the practitioner is expected to generate consulting dollars and a percentage of those earnings are used as overhead to support the university. The tenure decision could be based on the amount and quality of the consulting in the same manner as research is currently considered for research tenure track faculty. In return, the practitioner is provided equal status, equal pay and equal benefits.

- Promotion and tenure will continue to define what an institution considers important and will guide how faculty members behave. The ASCE Task Force on Redefining Scholarly Work noted that the main factors in granting tenure appear to be performance, temperament and long-term potential while promotion seems to be based solely on performance. The Task Force study<sup>15</sup> examined a model for evaluating faculty work that looked at service, teaching, and research along with the interface activities where these areas blend together. Most schools examined in the study use a rigid formula that assigns a percentage weight to performance in each of these areas. The percentage weights are rightly based on such things as the institutional mission, department mission and resources, size of the institution, accreditation criteria, classification of the institution, collective bargaining agreements, recent technology and research. The study proposes a more flexible solution using Bradley University as a case study. Based on the criteria listed above, the department defines an acceptable range of percentages in each of these domains and the faculty member chooses the percentage on which he or she will be judged from within a prescribed range. For example, the university may determine that teaching should be weighted somewhere between 35%-55% in the tenure decision. An individual faculty member whose primary strength is scholarship may choose to make that percentage 35% in her tenure evaluation. A different faculty member whose priority is classroom teaching may choose the 55% weighting for his evaluation. This type of increased flexibility may be needed more in the



future as different faculty members bring different skills to a department that has more diverse needs.

- If the world is changing fast and the future engineers need to be flexible and able to learn new subjects, perhaps the faculty need to be more nimble as well. The tenure process provides protection to faculty members who have met specific requirements and made substantial contributions in their disciplines. Tenure provides valuable protection in terms of academic freedom and shelter from short term, and perhaps short-sighted priorities that inhibit research with long term value. On the other hand, the system provides no incentive to adapt to changes in the discipline. Faculty are allowed to rest on their laurels in a world that is changing quickly. A system that forces faculty to be role models for life long learning and adaptability may better serve the students who will have to demonstrate the same attributes in the marketplace.

- It will always be difficult to devise a system where quality of teaching is given equal importance with research. Research is more easily measured in terms of publications and dollars generated. Effective teaching is more difficult to quantify and brings far less in monetary value to the university. Parents pay the same tuition whether the classroom teaching is stellar or abysmal. The reality may be that teaching will never be as important as research because education is a business. As operating funds provided by State tax dollars cover less of the costs of running a school, funds generated from research projects have to make up the difference. When the research funds are needed for survival, those who can attract those funds will be treated more favorably for both promotion and tenure.

- The quality of teaching has long term implications in terms of how many students choose to take engineering, can complete the program and learn the skills necessary to sustain them through a career in the engineering marketplace. Seymour and Hewitt's seminal study<sup>16</sup> as to why so many students leave the math, science, and engineering pointed to poor teaching as the primary cause. Their recommendations for improvement were more formalized training in how to teach, use of senior faculty to mentor less experienced faculty members, and a tenure and promotion system that rewards quality teaching. The ASCE has attempted to contribute to the first two elements through the ExCEED Teaching Workshops. The seven years of ExCEED workshops have to date provided 351 graduates from 179 colleges and universities.<sup>17</sup> Given the business practicalities of running a university, it may be impossible to put quality teaching on equal footing with research grants, but teaching can certainly achieve greater weight with regard to tenure decisions and faculty hiring. Perhaps the accreditation criteria need to include a provision in the faculty qualifications that requires adequate teacher training and a minimum level of teaching effectiveness. With respect to the faculty of the future, there needs to be recognition that teaching can be greatly improved through training, mentoring, and top-level administration emphasis. Prospective candidates at many schools have to teach a sample class as part of the interview process. Others have included attendance at ExCEED or some other teaching workshop as part of a new faculty start-up package. One key result should be the retention of quality students in the math, science, and engineering disciplines.

## **VI. Non-traditional Education Providers**

The college or university is the most accepted means of attaining higher level education and that environment forms the context of the discussion of the faculty of the future. In a world that demands adaptability and life-long learning, there are many other venues being developed for obtaining education. Breakthroughs in technology have helped make such options possible. The ASCE Fulfillment and Validation (F&V) Committee, a constituent sub-committee of CAP3 has been examining the multiple paths to meeting portions of the BOK, particularly at the post-baccalaureate level.<sup>18</sup> Education providers include ABET and non-ABET accredited universities, and non-university programs. The non-university programs include for profit providers, non-profit providers, private firms, and government agencies. For profit providers are often web-based courses that offer such things as management courses, continuing education, or preparation for licensing exams. They cater to a particular market and are free from many of the constraints and overhead of a traditional university. The non-profit providers are typically trade associations or professional societies who are providing education that supports a particular discipline. They generate revenue for the society and provide a service in terms of continuing education credits or professional development units to their members. ASCE, for example, holds approximately 300 open-enrollment seminars covering approximately 100 different technical and management topics, as well as more targeted on-site training programs. Depending on their size, many corporations manage their own training programs and some even have universities that provide professional development training and education to their employees. The quality of these programs vary, but because they are designed to make a private firm more competitive in the marketplace, many topics and courses support attainment of the Body of Knowledge. Similarly, government agencies such as the Department of Transportation and the Corps of Engineers run sophisticated educational programs on a variety of subjects. Some even have partnerships with existing universities where course credit is provided for the government courses. The University of Missouri at Rolla is one example where Army officers receive credit for courses taken as part of the Engineer Officer Advanced Course at Fort Leonard Wood.

As more options and alternatives become available, a major concern in the discussion of the faculty of the future is what considerations apply and how are they enforced. With regard to accreditation of these programs, the F&V committee is considering university sponsorship; established accreditation organizations such as ABET, American Council on Education (ACE) or NCEES; professional societies such as ASCE; State Licensing Boards; or employer verification. Ideally, the appropriate accreditation agency will assist in approving the faculty credentials as well. The bigger question is what those credentials should be. One could argue that the provider of web-based education has less of a responsibility to be a role model to students. That person does need to be capable of presenting the material in a clear, complete, and compelling manner and needs to have the experience and credentials to qualify as a subject matter expert. The exact requirements have not been sufficiently explored or discussed.

## **VII. Conclusions**

This paper discusses some relevant issues on the civil engineering faculty of the future. In many cases, it offers more questions than answers. As the ASCE Committee on Faculty Development revises the “who should teach” chapter for the BOK-2, such considerations need to be included in determining what the faculty of the future should look like. The engineering world and the

education system that supports it are changing rapidly. As civil engineering expands into new disciplines and the engineer of the future is expected to be more versatile, the education system needs to adapt to accommodate it. The faculty that comprise the educational system need to be flexible and agile as well, which means some of the traditional methods of hiring, promoting and retaining faculty need to change as well.

#### Acknowledgments

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Table 1. Who is Qualified Teacher to Teach the CE BOK

BOK Outcomes		Ph.D. in CE (research)	Masters in CE – some experience	Practitioner (Bachelors (+) 15+ years of experience)	Outside of CE discipline (Ph.D. or Masters)
1	Ability to apply knowledge of mathematics, science, and engineering	X	X	X	<b>XX</b>
2	Ability to design and conduct experiments, as well as analyze and interpret data	<b>XX</b>		<b>XX</b>	X
3	Ability to design a system, component or process to meet desired needs	X	X	<b>XX</b>	
4	Ability to function on multi-disciplinary teams	X		<b>XX</b>	X
5	Ability to identify, formulate, and solve engineering problems	<b>XX</b>	X	<b>XX</b>	
6	Understanding of professional and ethical responsibility	X	X	X	<b>XX</b>
7	Ability to communicate effectively	X	X	X	<b>XX</b>
8	The broad education necessary to understand the impact of engineering solutions in a global and societal context	X	X	<b>XX</b>	<b>XX</b>
9	Recognition of the need for, and an ability to engage in, life-long learning	<b>XX</b>		<b>XX</b>	X
10	Knowledge of contemporary issues			X	<b>XX</b>
11	Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	<b>XX</b>	X	X	
12	Ability to apply knowledge in a specialized area related to civil engineering	<b>XX</b>		<b>XX</b>	
13	Understanding of the elements of project management, construction, and asset management	<b>XX</b>	X	<b>XX</b>	
14	Understanding of business and public policy and administration fundamental			X	<b>XX</b>
15	Understanding of the role of the leader and leadership principles and attitudes			X	<b>XX</b>