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Recent Issues in Civil Engineering Education

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Abstract
The year 2008 has seen the publication of the second version of the report of the Body of Knowledge (BOK) Committee of American Society of Civil Engineering (ASCE). The report gives the opinion of eminenent engineers and academicians on what, how and by whom will be taught to 21st century's civil engineers. Starting from the 11 criteria of ABET, putting down measures for evaluating universities as to their outcomes, the BOK Committee ended with 24 criteria grouped under three major titles: Fundamentals, Technics and Professional Issues. Among these titles, the one that has seen the maximum attention is the third one, aiming to obtain civil engineers more open to social life. Another important issue in the work of the committee is the degree up to which these abilities will be given to candidates of civil engineering.

Keywords
Education, Engineering, Body of knowledge, Active design, Curriculum

1. Introduction

Education is a dynamic process. It has continually evolved in all senses since it formally began in Sumer (or with Kengers, as they called themselves) some 6000 years ago, and it seems that the evolution is not close to end. The same is true with engineering education, and specifically for civil engineering (CE) education. Although the terms engineer and civil engineer have a past of only a few centuries, there were masters who would easily carry these titles 5000 years ago, while designing and constructing the pyramids in Egypt, and those who had built greater pyramids in Central Asia some 1000 years before the Egyptians.

The term engineer, as "ingenieur" in French, started to be used after mid-1600s, for the people who were capable of making calculations and applications about artillery, fortifications, and river crossings in the armies. Those people, mostly officers, were literate of mathematics and mechanics knowledge of the day necessitated by the complex works they were performing. Later, the term civil engineer came into use for the people who were doing similar works in the civil life.

In 1716, a body was formed bearing the name "le corps des ingénieurs des Ponts et Chaussées" (Body of Bridge and Highway Engineers). In February 14, 1747, the king's decree has transformed this body to a school. Until 1794, the school is marked by its Director, Jean-Rodolphe Perronet who was a engineer, administrator and a partricipant in the preparation of the l'Encyclopédie of d'Alembert and Diderot. At the beginning, the school had about 50 students and not a single instructor. In fact, they were self-teaching theoretically, and were completing their knowledge by practices on sites. As time went on, the education has changed its structure. After the the French Revolution of 1789, Napoleon made a reorganization of engineering education by opening the Ecole Polytechnique (Polytechnical School) in 1794 with a wider scope of subject (www 01)[1].

Following France, engineering education has started in other countries, like USA and British Empire and than in the whole world, including the Ottoman Empire. Since the start of the formal civil engineering education, there has been numerous changes in the duration, objective, definition, curriculum, and other parameters of civil engineering education, some of which could be called as reforms. In fact, all these are the steps in evolutionary development of educating civil engineering candidates.

Very recently, some steps are being considered in this process. In this paper, these steps are being discussed.

2. Body of Knowledge

American Society of Civil Engineers (ASCE) has started a study to determine what knowledge and abilities will be given to civil engineers of the 21st century, who will be charged in this task, and how this task will be accomplished. A committee has been formed for this purpose, named "Body of Knowledge (BOK) Committee of the Committee on Academic Prerequisites for Professional Practice". This committee published the first BOK (BOK1) in January 2004. The outputs presented in this publication are reviewed in a long process which encompassed an important workhop in Istanbul (Toklu, 2006). At the end, ASCE released the *Civil Engineering Body of Knowledge for the 21st Century, Second Edition* (abbreviated as "BOK2") on February 19, 2008 at a special event at the National Academy of Engineering. The author of this paper was a corresponding member of the BOK Committee.

In BOK1, there were 15 items which were the subjects to be given to civil engineering students. 11 of these were directly influenced by those used by Accreditation Board for Engineering and Technology (ABET). In BOK2, the total number of items is increased to 24, not by adding new subjects but by increasing the clarity. These items are given in Table 1. It can be seen that 4 of these items relate to foundational outcomes, 11 of them are technical outcomes and the remaining 9 are professional outcomes.

It can also be seen that these 24 outcomes are an extended version of ABET and its Turkish equivalent (Mühendislik Egitim Programları Degerlendirme ve Akreditasyon Dernegi – MÜDEK) criteria (Şenatalar *et al*, 2005), the extensions being especially in the last two groups. An interpretation for this is the emphasize on preparing the civil engineering candidates to real future life where they are expected to assume social responsibilities as well as technical skills and abilities.

These changes are in complete accordance with the Unesco's 2005 recommendations on higher education: "The core missions of higher education systems (to educate, to train, to undertake research and, in particular, to contribute to the sustainable development and improvement of society as a whole) should be preserved, reinforced and further expanded, namely to educate highly qualified graduates and responsible citizens and to provide opportunities (espaces ouverts) for higher learning and for learning throughout life. Moreover, higher education has acquired an unprecedented role in present-day society, as a vital component of cultural, social, economic and political development and as a pillar of endogenous capacity-building, the consolidation of human rights, sustainable development, democracy and peace, in a context of justice. It is the duty of higher education to ensure that the values and ideals of a culture of peace prevail" (www 02).

[1] Notes in the form (www xx) refers to web reference number xx given at the end of the References.

Table 1: 24 Outcomes Expected From Civil Engineers According to BOK2

Outcome number and title	To enter the practice of civil engineering at the professional level, an individual must be able to demonstrate this level of achievement
Foundational Outcomes	
1 Mathematics	***Solve*** problems in mathematics through differential equations and ***apply*** this knowledge to the solution of engineering problems. **(L3)**
2 Natural Sciences	***Solve*** problems in calculus-based physics, chemistry, and one additional area of natural science and ***apply*** this knowledge to the solution of engineering problems. **(L3)**
3 Humanities	***Demonstrate*** the importance of the humanities in the professional practice of engineering **(L3)**
4 Social sciences	***Demonstrate*** the incorporation of social sciences knowledge into the professional practice of engineering. **(L3)**
Technical Outcomes	
5 Materials science	**Use** knowledge of materials science to ***solve*** problems appropriate to civil engineering. **(L3)**
6 Mechanics	**Analyze** and solve problems in solid and fluid mechanics. **(L4)**
7 Experiments	***Specify*** an experiment to meet a need, conduct the experiment, and analyze and ***explain*** the resulting data. **(L5)**
8 Problem recognition and solving	***Formulate*** and solve an ill-defined engineering problem appropriate to civil engineering by ***selecting*** and applying appropriate techniques and tools. **(L4)**
9 Design	***Evaluate*** the design of a complex system, component, or process and ***assess*** compliance with customary standards of practice, user's and project's needs, and relevant constraints. **(L6)**
10 Sustainability	***Analyze*** systems of engineered works, whether traditional or emergent, for sustainable performance. **(L4)**
11 Contemporary issues and historical perspectives	***Analyze, compare,*** and ***contrast*** the economic, environmental, political, and societal impacts of engineering. **(L4)**
12 Risk and uncertainty	***Analyze*** the loading and capacity, and the effects of their respective uncertainties, for a well-defined design and ***illustrate*** the underlying probability of failure (or non-performance) for a specified failure mode. **(L4)**
13 Project management	***Formulate*** documents to be incorporated into the project management plan. **(L4)**
14 Breadth in civil engineering areas	***Analyze*** and solve well-defined engineering problems in at least four technical areas appropriate to civil engineering. **(L4)**
15 Technical specialization	***Evaluate*** the design of a complex system or process, or ***evaluate*** the validity of newly-created knowledge or technologies in a traditional or emerging advanced specialized technical area appropriate to civil engineering. **(L6)**

Professional Outcomes	
16 Communication	***Plan, compose,*** and ***integrate*** the verbal, written, virtual, and graphical communication of a project to technical and non-technical audiences. **(L5)**
17 Public policy	***Apply*** public policy process techniques to simple public policy problems related to civil engineering works. **(L3)**
18 Business and public administration	***Apply*** business and public administration concepts and processes. **(L3)**
19 Globalization	***Analyze*** engineering works and services delivered in a global context. **(L4)**
20 Leadership	***Organize*** and ***direct*** the efforts of a group. **(L4)**
21 Teamwork	***Function*** effectively as a member of a multi-disciplinary team. **(L4)**
22 Attitudes	***Demonstrate*** attitudes supportive of the professional practice of civil engineering. **(L3)**
23 Life-long learning	***Plan*** and ***execute*** the acquisition of required expertise appropriate for professional practice. **(L5)**
24 Professional and ethical responsibility	***Justify*** a solution to an engineering problem based on professional and ethical standards and ***assess*** personal professional and ethical development. **(L6)**

One more interesting issue in BOK2 is based on the levels at which these outcomes will be required from CE students. It is obvious that some of these items will be dealt with more emphasize, some others will be given to the students at a less elaborate level. At the beginning, these leveles were expressed with the words recognition, understanding, and ability. Considering that use of these words was introducing ambiguity to the description of levels, it is decided to use Bloom’s Taxonomy (Bloom, 1956) to define levels of achievement. According to this taxonomy, the levels of learning are;

Level 1 **(L1)** - Knowledge
Level 2 **(L2)** - Comprehension
Level 3 **(L3)** - Application
Level 4 **(L4)** - Analysis
Level 5 **(L5)** - Synthesis
Level 6 **(L6)** – Evaluation.

Table 2 gives the levels which the CE candidates will be required to attain for each item. Those cells marked “BS” in this table indicates that the related level will be reached during Bachelor of Science studies. The label “MS/30” means 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” means the pre-licensure experience.

3. Recent Computational Issues in Civil Engineering

Wıth the advances in computers, both in hardware and software, engineering has changed unmeasurably in the past few decades, and this change is continuing with an increasing speed. This has caused all civil engineering institutions to take some measures for educating civil engineers or civil engineering candidates on computational aspects. In this context, one may count two committes in ASCE:

i) Committee on Emerging Computational Techniques in Civil Enginering (ECT)
ii) Center of Excellence of Computing in Civil Enginering (COEC)

The first of these, ECT, as its name implies, is working on new computational techniques being introduced in civil engineering. Advances in hardware made computers much more quick in making calculations and their memories became incomparably large as compared to preceeding models of computers. Advances in software made computer programs much more capable and maniable. These advances made it possible to put forth new algorithms that were inconcievable before. The aim of ECT is to find ways for introducing these algorithms in civil engineering curricula in the most appropriate way.

The second one, working more internationally than the first one, is trying put together all information necessary for forming a curriculum related to computing in civil engineering and to find the best system for teaching future civil engineers recent techniques of computing.

Table 2: Fulfilling 24 Outcomes to the Various Levels of Achievement

Outcome number and title	Level of achievement					
	1 Know-ledge	2 Compre-hension	3 Appli-cation	4 Analy-sis	5 Synthe-sis	6 Evalu-ation
Foundational						
1. Mathematics	BS	BS	BS			
2. Natural sciences	BS	BS	BS			
3. Humanities	BS	BS	BS			
4. Social sciences	BS	BS	BS			
Technical						
5. Materials science	BS	BS	BS			
6. Mechanics	BS	BS	BS	BS		
7. Experiments	BS	BS	BS	BS	MS/30	
8. Problem recognition and solving	BS	BS	BS	MS/30		
9. Design	BS	BS	BS	BS	BS	E
10. Sustainability	BS	BS	BS	E		
11. Contemp. Issues & hist. Perspectives	BS	BS	BS	E		
12. Risk and uncertainty	BS	BS	BS	E		
13. Project management	BS	BS	BS	E		
14. Breadth in civil engineering areas	BS	BS	BS	BS		
15. Technical specialization	BS	MS/30	MS/30	MS/30	MS/30	E
Professional						
16. Communication	BS	BS	BS	BS	E	
17. Public policy	BS	BS	E			
18. Business and public administration	BS	BS	E			
19. Globalization	BS	BS	BS	E		
20. Leadership	BS	BS	BS	E		
21. Teamwork	BS	BS	BS	E		
22. Attitudes	BS	BS	E			
23. Life-long learning	BS	BS	BS	E	E	
24. Professional and ethical responsibility	BS	BS	BS	BS	E	E

COEC has the goal "To advance computing in civil engineering for use in research, education, and practice" (Arciszewski *et al*., 2007). Presently, the top priority of the Center is computing education. For this purpose, the Center began working on development of teaching modules. These modules are classifed under 7 titles:

1. Theoretical Foundations
2. Building Knowledge Representations
3. Acquiring Data and Knowledge
4. Information Storage
5. Information Processing
6. Knowledge Utilization
7. Engineer-Computer Interaction

It is hoped that with the help of the lectures enriched by documents, civil engineers all over the world, will be much more aware of new computational advances.

4. Further Issues

The efforts mentioned above does not seem to be conclusive even for the current period. Their conclusions will still leave many issues to be dealt with. One can count among them easily the following:

- Optimization is not covered in the civil engineering curricula in the depth it deserves. With the metaheuristic techniques developed and being developed recently, optimization algorithms have proved themselves very powerful in solving almost all types of engineering problems (Toklu 2004).
- Civil engineering candidates are still educated to be more analytical then synthetical.
- Active design and active structures are not dealt with in civil engineering curricula. In fact, time has come moving away from passive design and passive structures and passing to active, and even smart or intelligent design and structures (Liu *et al*, 2005).
- Automation in construction is still not taken into consideration in civil engineering curricula.
- Interfaces between civil engineering and new technologies like nanotechnology are still at the level of infantry.
- The engineers are still taught to think deterministically without considering the stochastic nature of many processes.
- In most of the curricula, the system science approach is way back then looking to the problems in an isolated way.
- The students are not taught to make applications in harsh environments. This approach prevents and will prevent civil engineers to deal with civil engineering problems in, for example, extraterrestrial areas.

These and similar issues are waiting to be dealt with in civil engineering education.

5. Conclusions

With the advances in science and technology, the knowledge, skills and abilities of civil engineers are facing new challenges. There are many attempts to improve civil engineering education in order to produce civil engineers who will be effective in say 30, 50 years from now, that is at the middle of the 21st century. Unfortunately the attempts seem to be insufficient for reaching this goal. Much more studies are needed to form these future engineers to handle the problems of tomorrow.

6. References

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