International Workshop on Reforming Civil and Environmental Engineering Education Given the Societal Challenges Related to Infrastructures
(**Istanbul, Turkey, October 4-7,** http://www.eng.bahcesehir.edu.tr/educee/)

Background: A recent National Academy of Engineering study (Engineer 2020) identified the following societal challenges that require effective solutions by engineering ingenuity: (a) decaying of physical infrastructures in urban settings, (b) assuring the growth and performance of the newly developing critical communication and information infrastructures, their maintenance, management and protection, (c) concerns related to the environment and climate change, (c) destruction and depletion of natural resources and non-renewable sources of energy, (d) aging of industrialized societies, (e) population growth and socio-economic tensions in the developing world.

The same study identified opportunities inherent in the emergence and growth of: (a) information and communication technologies, (b) bioengineering, biotechnology and biomedical technology, (c) micro-and-nanotechnologies, (d) smart materials and systems, to help address the listed challenges. However, how we may take advantage of these opportunities for effectively responding to the challenges listed above is yet unresolved. Factors such as industrialization, urbanization, and environmental degradation, socio-political tensions around the world, rising concerns regarding the social implications of rapid technological advance, the growing diversity of the workforce, an increased focus on managed risk and assessment with a view to public security, privacy, and safety are additional parameters that affect how engineers need to leverage technology to address the above listed challenges.

Naturally, the leveraging of technology has to be in context with the speed of technological change and the explosion in the amount of data and information that is becoming available, the globalization of industry and engineering practice, the shift of engineering employment from large companies to small and medium-sized companies and the growing emphasis on entrepreneurialism, the growing share of engineering employment in non-traditional, less-technical engineering work (e.g., management, finance, marketing, policy), the shift to a knowledge-based "services" economy, and, the increasing productivity gains by using technology in the work, education and continuing education of the engineer.

State of Civil and Environmental Engineering Practice and Education: Professional societies of various engineering disciplines such as IEEE, ASME and ACS have been quite active in recognizing the above challenges and conducting research on curriculum innovation. However, in spite of extensive discussions and efforts by ASCE and ABET since the 1990's, civil engineering academe do not appear to be as active in curriculum innovation research and in exploring how to leverage technology to advance their education and practice, evidenced by the very few NSF education grants to civil engineering. One of the possible reasons for this may be the fragmentation of civil and environmental engineering into too many distinct specializations with little interaction, and a general lack of integrative, systemic approaches to curriculum reform.

Civil and environmental engineers have acquired by far the least amount of reliable and objective knowledge of the characteristics and the lifecycle performance of their products, i.e. the constructed elements of critical infrastructures. This is mainly due to the **very large geometric and temporal scales of constructed systems that do not lend themselves to be easily physically conceptualized by average human cognitive abilities.** The problem is compounded by the highly fragmented and often not fully documented manner in which even major constructed systems are planned and financed, designed, fabricated, erected, constructed, operated, maintained and managed along their many decades-long lifecycles. Due to a lack of sufficient systemic-generic knowledge, significant epistemic uncertainty hinders reliable analytical modeling for predicting the structural properties, behavior and performance of soil-foundation-structural systems.

Recognizing that infrastructures are complex intertwined systems with engineered, human and natural sub-systems and elements, and, that constructed systems cannot be engineered or managed without a full understanding of the critical interactions that prevail between them and other engineered, human and natural elements of their parent infrastructure systems, we have to fully embrace, transform and leverage systems engineering concepts and tools in civil and environmental engineering education, research and practice. Although a number of prestigious university programs have been offering an "applied science" based civil engineering education for providing a systems approach to problems, more than 240 programs educating nearly all of the about 8000 BS and 3750 MS degrees awarded in civil and environmental engineering in North America (ASEE, 2004), follow curricula with some applied science content but generally heavily weighed with a prescriptive approach to design. While the most recent ASCE and ABET criteria (2004) now offer great freedom to programs, there has been little specificity or guidance to how a program may take advantage of this freedom and incorporate a proper weighing of applied science and systems-based education to their constituents.

As we recognize the need for a systems-based education of civil and environmental engineers, at the same time we cannot ignore that engineering design remains more art than science, and art education requires not just some element of apprenticeship, but more importantly, in the case of engineering art that has evolved over Centuries such as civil engineering, ***the ability to synthesize heuristics.*** We cannot ignore that the craft skills that defined engineering until the 1800's, led to the creation of impressive constructed systems some of which remain as monuments still in use. Therefore, we need to maintain the craft skills in civil engineering as an element of our contemporary education.

The premise in applied-science based engineering education is that an engineer may receive a level of apprenticeship and may get exposed to heuristics following graduation. This is in fact quite true in the case of emerging and highly dynamic disciplines that are led by their respective industries, such as electronics, aerospace, automotive, information technology, chemical-pharmaceutical, bioengineering, etc***. However, in the field of civil and environmental engineering, there is sufficient evidence noted by NAE's Engineer 2020 that the principal employers, i.e. the consulting and construction industries as well as the government may not be able to offer a proper synthesis of the heuristics that is necessary to design effective solutions to the problems related to the engineering and management of the constructed environment.***

It follows that civil and environmental engineering education is facing the dilemma of balancing the needs for properly teaching: (a) systems engineering concepts and tools that still have to be transformed to large-scale infrastructure system-of-systems; (b) civil engineering crafts (making field measurements, constructing physical and analytical models, communicating through engineering drawings, etc), and, (c) a synthesis of heuristics (e.g. understanding structural forms and the proper materials for creating structural systems for different purposes, physically conceptualizing the flow of forces through structural systems of various forms and materials, visualizing the kinematics of complex 3D structural systems, designing constructed systems based on a series of complex performance limit-states with highly uncertain demand and capacity envelopes, and, understanding and evaluating risk and reliability in making decisions related to complex systems problems, etc). In addition, we cannot ignore the importance of increasing the: (d) liberal arts content to humanize engineering, and, (e) continue offering some level of prescriptive design for those students who are qualified to enter the workforce only at the lowest rung.

Whether making the Masters degree the lowest degree for entering the professional ranks will sufficiently address this dilemma, or that it is an over-simple solution reached without fully grasping the scope of the problems we face needs further discussion by qualified parties. What we therefore propose is to create a sufficient critical mass of educators and practicing engineers who understand the complex systems nature of the problems we face as a society, who share the same vision and have sufficient experience to define the "new fundamentals" for educating the future civil and environmental engineers.

We are convinced that by encouraging these renaissance engineers to come together and to construct model curricula, with a sufficient level of specificity and clear standards of depth, rigor and quality of delivery, we would make a difference by demonstrating how the future civil and environmental engineering students may be guided through a properly balanced applied science, systems engineering and, civil engineering arts and crafts education. This is the motivation for organizing the workshop described in the following.

Objectives and Deliverables of the Workshop: Reforming Civil and Environmental Engineering Education Given the Societal Challenges Related to Infrastructures

1. Review the drivers associated with the innovations and renaissance in various engineering fields and engineering education in general, and discuss how the same drivers and societal concerns are pressing for reform in civil and environmental engineering (CEE) practice and education. Establish a consensus on the relevancy of a set of ***"new fundamentals"*** for engineering. These may include information technology, bio-engineering, nano-scale technologies, skills and understanding necessary for effectively leading multi-disciplinary teams, the challenges of framing and addressing large-scale system-of-systems problems, sustainability, lifecycle management of systems, risk-based asset management, the need for lifelong learning, globalization, demographic realities and need for diversity, etc. ***Especially, we are interested in a review and synthesis of ongoing efforts by various programs and countries to specifically address the increasingly global nature of civil and environmental engineering practice in education.***

2. Discuss how we can select, package and deliver the critical set of ***remaining "classical fundamentals of civil engineering"*** that also have to be established. For example, mechanics, materials, structural modeling and analysis, uncertainty, risk and reliability, element and system-level behavior and design, core knowledge of select concentration areas such as geotechnical, water resources, environmental, transportation, construction, etc., and the other elements of ASCE's BOK ***both to preserve them and also take advantage of them as a means of teaching the new fundamentals*****?** Related to this we need to openly discuss whether there really is a necessity for civil and environmental engineers in the future, or whether another discipline such as industrial engineering may be better suited to address the societal problems that Civil Engineers have been ineffective in addressing. If there is a necessity for CEE, what would be the minimum required skill-set and knowledge that their education has to provide so that they may serve the society as needed? If the answer is affirmative, we then need to discuss the consequences of failing to educate sufficient numbers of renaissance civil and environmental engineers in the next 20 years for the society?

3. ***Formulate a road-map for constructing a highly flexible, global core curriculum for the future's global renaissance civil and environmental engineer***, including sufficient examples for the minimum delivery standards and associated pedagogical tools that are required for its successful mastery given the differences in the culture and college preparation of current and future students at various parts of the world. ***Together with this curriculum, we have to formulate how we may successfully prepare tomorrow's civil and environmental engineering educators?***

Deliverables: During this workshop international collaborations will be initiated for a global renaissance CEE curriculum development effort. This effort will include detailed descriptions of the minimum delivery standards, the experimental, analytical and numerical tools, and the pedagogical considerations recognizing the regional cultural attributes and preparation quality of students. An advisory committee of elders and an action committee of younger civil engineering educators will be formed to coordinate various working groups that will hold future meetings, workshops and congresses. Proposals will be formulated to appropriate NSF, EC, TUBITAK and similar agencies around the globe for developing each of the critical elements of the curriculum for renaissance CEE. The workshop report and the products of these follow-up efforts will be maintained on a web site for global use.

Participants, Program and Modus Operandi of the Workshop: The participants will be civil and environmental engineering educators and practicing engineers from US, Canada, EC, Middle East and the Far East. We anticipate about 60 invited participants including university administrators, representatives of agencies that are concerned with engineering education, and representatives of employers of CEE's from government agencies and industry. The workshop program will incorporate invited presentations and discussions during the first two days, followed by a third day of panel meetings. Advisory and action committee's will be formed to continue with the construction of a global core curriculum at the end of the third day. These committee's will comprise a smaller working group that will meet and work for an additional day, and draft the conclusions and future action plan resulting from the workshop.

Tentative Program: Reforming Civil and Environmental Engineering Education

1. Introductions and Welcome (Day 1)
Organizing Committee: Drs. Toklu, Pala, Ergun and Aktan
Turkish Higher Education Representative
Host: President, Bahcesehir University

2. Agency and Institutional Views on a Global Renaissance, and, New and Classical Fundamentals (Objectives 1 and 2):
Faruk Karadogan (President, Istanbul Technical University)
President, Turkish Science and Technology Council (TUBITAK)
Steven Director (US National Academy of Engineering, The Engineer 2020 Initiative)
Richard O. Anderson (Chair, ASCE BOK and Past President, ABET)
Douglas Foutch (Program Manager, US National Science Foundation)
Hamid Ghasemi (Program Manager, USDOT, Federal Highway Administration)

3. Educators Views on Global Renaissance:
Adnan Akay (CMU and NSF): The Need for a Renaissance in Doctoral Education in Engineering
Nicholas Jones (JHU): Possible Strategies for Education Reform Based on Program Size and Traditions
Aftab Mufti (ISIS-Canada): The Canadian perspective (ISIS), and, ISHMII (www.ishmii.org)
Helmut Wenzel (SAMCO, EC): The EC perspective and SAMCO (www.samco.org)
Hitoshi Furuta (Kansai U): The Japanese perspective
Ergun Togrol and Ersin Arioglu (ITU): The Turkish perspective

4. Educators Views on the New (and Classical) Fundamentals: (Day 2)
Raimondo Betti (Columbia): Engineering and Structural Mechanics
Helmut Krawinkler (Stanford): Earthquake/Structural Engineering
Oral Buyukozturk (MIT): Materials and Systems
Pratim Biswas (WUStL): Environmental Engineering and Science
Mehmet Tumay (LSU): Geotechnical and Geo-Environmental Engineering
Jeanne VanBriesen (CMU) - tentative: Water Systems
David Arditi (IIT): Construction Engineering
Gokmen Ergun (Bogazici U): Transportation Engineering
Hasan Akay (Purdue/Indiana U): Information Technology in Engineering
Franklin Moon and Emin Aktan (Drexel U): Infrastructure Systems Engineering and Management
Visit to St Sophia and the Blue Mosque

5. Working groups for a Roadmap to a Global Curriculum for Renaissance CEE (Day 3)
Presentations by Working Groups - Objective 3
Formation of Advisory and Action Committees
Visit to the Bosphorus Bridge and Closing of the Workshop at Dinner
Note: Advisory and Action Committees will meet for another day (Day 4) to formulate the conclusions of the Workshop and draft a 3-Year Action Agenda for designing and detailing a global CEE curriculum.