TECHNICAL CREATIVITY AND THE FUTURE OF ENGINEERING EDUCATION

With the complexity surrounding every engineering project mounting as natural resources dwindle, the world population increases, and the global infrastructure and economy grow ever more intertwined, the creativity and innovation necessary to address the big issues facing civilization - maintaining the infrastructure; providing food, water, shelter, and power to the population; and growing sustainably and safely - will only increase in importance.

What is Creativity?

The late Dr. E. Paul Torrance, a pioneering creativity researcher for over 60 years, is widely considered the "*Father of Creativity*". He made it his life's work to study the nature of creativity and how it can be taught to students of all ages. Among his numerous contributions was groundbreaking research in educational psychology that led to a benchmark method for quantifying creativity. His "*Torrance Tests of Creative Thinking*" effectively debunked the common assumption that IQ alone determined creativity. It also led to the now accepted belief that creative levels can be increased through practice. Torrance defined creativity as "*the process of sensing problems or gaps in information, forming ideas of hypotheses, testing, and modifying these hypotheses, and communicating the results. This process may lead to any one of many kinds of products - verbal and nonverbal, concrete and abstract*". This definition subsumes such creative "*products*" as works of art, but through the intentional use of scientific terminology (e.g., "*hypotheses*"), Torrance intended a more inclusive definition that included "*inventions, medical discoveries, books, monographs*". Clearly Torrance looked for creativity in science and engineering just as he did in theater and English departments. Several other educators have offered definitions for creativity as it applies to engineering. It has been described as "*the awareness, observation, imagination, conceptualization, and rearrangement of existing elements to generate new ideas*". Goldsmith described it as "*The production and disclosure of a new fact, law, relationship, device or product, process, or system based generally on available knowledge but not following directly, easily, simply, or even by usual logical processes from the guiding information at hand*". Pereira defined creativity as "*the capacity to perform mental work that leads to an outcome both novel and applicable*".

The creative thought, then, is something that leads to the creative act or the creation of something new - an idea, theory, or physical product. When approaching technical matters, the term "innovation" is often used instead of creativity to describe the process that leads to insight or progress in a field, with a technique, or with a physical product. While innovation connotes a sense of inventing a thing as opposed to an idea or a theory, it is essentially a synonym for the creative process. Perhaps technical people prefer to be "*innovative*" rather than "*creative*". Regardless of what you call it, both innovation and creativity should lead one to the same end: to the exciting world of inventing and creating new knowledge, processes, and artefacts that push forward our science, technology, and art.

The Creative Process

The notion of a lone genius thinking up something brilliant and changing the world is a myth that has fortunately been debunked. Most people who study creativity now accept the notion that creativity is not something that happens in a vacuum. The definitions presented above articulate the notion that creativity is a process rooted in the real world. Every process has components, and the essential stages in the creative process include:

- Sensing, testing, modifying, and communicating (Torrance 1963);
- Orientation, preparation, analysis, ideation, incubation, synthesis, and evaluation (Osborn
- 1953); and
- Problem definition, preparation, incubation, illumination, and verification (Farid et al.
- 1993).

The creative process must go through a series of four stages, beginning with:

- a notion or need (sensing, problem definition, and orientation);

- an investigation of that notion or need (testing, preparation, incubation, analysis, and ideation);

- an articulation of a new idea or solution (modifying, illumination, and synthesis);

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- a validation process of that idea or solution resulting in an idea, theory, process, or physical product (communicating, verification, and evaluation).

These four stages should be familiar to engineers, as they more or less mirror the design process itself, which never forget is (or should be) a creative endeavour. For example: the client approaches the engineer with a need; the engineering firm investigates the project parameters and potential solutions, often through a design team or charette approach; the engineering firm presents its plan to the client; after numerous iterations, the final design is formalized. Countless variations of this simplified process exist, but hopefully it is apparent that, at its base, the engineering process is compatible with a creative process.

Should Engineers Strive To Be Creative?

The insight and understanding that civil engineers possess could immeasurably enhance the effort to solve the crucial issues facing the 21st century such as maintaining the infrastructure, providing clean water and food, and protecting the environment. Creative solutions to these big issues are essential to the health, viability, and continuation of civil society in the 21st century. Yet far from leading the effort to build more efficiently, with less waste, and in a safer manner, civil engineers very often follow the age-old project model and provide valuable technical services without creative input or leadership. The market for civil engineering design and consulting services is not likely to diminish in the 21st century; the only questions are what role civil engineers will play in determining the scope of their contributions and the market value for these services. The issue quickly becomes can civil engineers afford not to be creative?

The problem of creativity in civil engineering begins at the base. Civil engineering as a profession (and engineering in general) has not been intentional about educating students to become creative in their application of their technical and professional skills. Said another way, the value of creativity is not explicitly communicated to students as a priority of their education. Yet even in the most technical of positions, civil engineers must find novel and unique ways to approach and solve design challenges, whether this means placing piping in unique formations or finding a way to stabilize soil in a nontraditional manner.

Consider for a moment a massive public works project that has taxed the abilities of the civil engineering profession and the construction industry. The Central Artery/Tunnel in Boston, known as the Big Dig, has been called "*the biggest, most complex, and most expensive highway engineering job in U.S. history*" (Vizard 2001), as well as "*the largest publics works project ever undertaken in the history of the United States*" (Bushouse 2002). Rerouting over 200,000 vehicles a day without ceasing traffic, gaining and keeping public approval, and acquiring the necessary environmental permits have been just a few of the many challenges requiring significant communication, leadership, systems thinking, and creative problem solving from many project participants. Keeping existing roads operational has necessitated innovative management techniques and construction methods, including the use of global positioning technology, laser measuring tools, and the use of slurry walls, ground freezing, and chemical stabilization of soil (Angelo 2001).

Yet for all its success - and when completed, the project will help revitalize and change a historic, economically important downtown - The Big Dig has gone way over budget and suffered from oversight, unforeseen consequences, and contractor bankruptcy. While the Big Dig may be an extreme example - clearly it is at the edge of the project spectrum - it can still serve as a touchstone and as a warning for civil engineering and engineering as a whole. In the 21st century, 20th-century solutions and thinking are not going to get the job done. How is the global community going to rebuild Iraq? How is the U.S. going to build less vulnerable and more secure facilities? How can we continue to update the aging infrastructure in our nation's cities without interrupting the flow of commuters and commerce? And how can we solve the as yet - unheard-of problems that will inevitably arise as the world grows smaller and opportunity costs loom larger?

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