EEES
Engineering Equity Extension Service

CHANGE: Changing Problem-Solving in Engineering Courses

Overview of the Research

Several scholars—many melding degrees and work experience in engineering with social-science preparation—suggest that the nature of activities done by students in core engineering classes could change in ways that would make graduates better engineers. Such course changes would result in students who are better able to solve problems that have ambiguity, have better connections to the real world, require reflection, and promote the understanding of engineering as an activity that requires problem solving *with* people (who often come with different technical and non-technical preparation, as well as different perspectives on the world and on engineering solutions that impact those worlds). These ideas, then, are the focus of this paper.

Studies of engineering work suggest that several forms of knowledge are needed to succeed as an engineer (Table 1) [2-5]. Ranging across different types of engineering work, from research and design to production, or in hybrid kinds of engineering work like environmental engineering, the work of engineers requires understandings that go beyond the formal knowledge taught in typical engineering courses. In fact, such research studies suggest the need for a "heterogeneous" engineer, one with proficiency in multiple forms of knowledge [6,7].

Ethnographic studies of engineering education, however, illuminate the mismatch between engineering proficiencies and traditional engineering educational practices [8-11]. Not only do campus practices draw students toward formal knowledge, but also courses where the other forms of knowledge are given prominence, notably design courses, are resisted by students [9, 12] and those proficient here receive little recognition [14]. Thus, a mismatch between engineering work and education persists, in spite of efforts to effect substantive change [15].

Therefore, some scholars have called for new types of reform, especially for reform in the problem-solving tradition used in core courses [9,17]. Arguing that engineering is fundamentally a social world, as opposed to an "object" world of mathematized abstractions, Bucciarelli and Kuhn suggested that engineering education teach graduates how to "deal with context" [16, p. 220]. That is, problem-solving would shift from a single-answer problem and "challenge [students] to critically reflect upon what they are doing, and require them to articulate and defend their choices of method and designs in front of peers and faculty" [16, p. 220]

Recommended Actions for CHANGE

Thus, rather than isolating other forms of knowledge solely in design courses, core courses would incorporate a new kind of problem, that goes beyond a one-right-answer notion of excellence.

Table 1. Components and contexts of knowledge (adapted from Fleck [1], p. 153)

Components of Knowledge	Embodied in...
Formal knowledge: *theories, formula, available in written form, e.g. textbooks, acquired through formal education*	Codified theories
Instrumentalities: *knowledge embodied in the use of tools and instruments, learned through demonstration and practice*	Tool use
Informal knowledge: *rules of thumb, tricks of the trade, sometimes available in guidebooks, etc.*	Verbal interaction
Contingent knowledge: *distributed apparently trivial knowledge, acquired by on-the-spot learning*	Specific contexts
Tacit knowledge: *rooted in practice and experience, transmitted by apprenticeship and training*	People
Meta-knowledge: *general cultural and philosophical assumptions, acquired through socialization*	Organizations

- **Introduce Ambiguity into Courses**

Bucciarelli and Kuhn [13] recommend recasting problems to introduce ambiguity and move the engineer and other people into the equation. For instance, instead of a lawn mower with a fixed handle at a certain angle rolling over a specified step and determining the force required to move over the step (accompanied with an illustration reducing the "givens" to geometric shapes), they suggest students analyze a hospital bed for indoor use that must occasionally roll over small obstacles, pushed by an attendant, and provide a rationale for the wheel size and determine a range of possible parameters. They argue that giving students time in core courses to struggle with these kinds of problems ultimately produces better engineers.

Such new problem-solving modes prepare students to continuously learn on the job [14], an especially important skill in engineering fields with less stable knowledge or in emerging fields, such as environmental engineering [4]. With the globalization of engineering work, it seems likely that this will become the norm in most engineering specialties, rather than the exception. In particular, engineering graduates must have a capacity for reflexive thinking—the continued education of professionals in a combination of educational and practice learning [4, p. 57]. Because of rapidly changing policies, regulations, and other influences, engineers in all sites of practice must be capable of continuously learning, something that ABET criteria expect graduates to demonstrate [17].

- **Prepare Students for Global Practice**

Downey and Lucena suggest that U.S. engineers need better preparation for transnational careers, whether working for U.S. or other companies outside the U.S., or working in the U.S. for companies with corporate offices and cultures elsewhere [18]. They developed an integrated liberal arts course—Engineering Cultures—to help students "learn to work with people who define problems differently than they do" [p. 256]. Here, students study the emergence of engineers and engineering in different countries, ultimately realizing that there have been different paths, with different sorts of engineers produced. Five modules are available on multimedia CDs. (More information is on Downey's Engineering Cultures website: http://www.engcultures.sts.vt.edu/overview.html)

Changing problem-solving practices to provide students experiences that foster developing instrumental, informal, contingent, tacit, and meta-knowledge and that foster reflective thinking and train engineers to work *with* people who define a particular problem differently helps engineering graduates become engineers who can succeed in engineering as the profession continues to change.

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