Addressing Issues Related to Technology and Engineering

An Interview with Michael Hacker and David Burghardt

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Question 1. Over the past decade, you have done considerable research pertaining to the overlapping principles, concepts, and activities related to technology and engineering. What are a few of the key characteristics that you have found?

Response 1. We've done a research-based comparison of the professional competencies required by ABET for engineers and by NCATE for technology teachers. The comparison in Table 1 shows a focus on rigorous technical content preparation for both groups, an emphasis on mathematics and science for engineers, and on pedagogy for teachers. There is a high degree of alignment with respect to other competencies and both professional groups are well prepared in areas of professional practice, design and problem solving, team functioning, ethical and professional responsibility, communication skills, social and cultural impacts, and professional growth.

A major area of congruence is the focus on design as the core process that underlies engineering and technological development. ABET defines engineering design as "the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs [ABET, 2008]."

A clear difference is how engineers are rigorously prepared in mathematics and science. In the area of knowledge application, engineers are well prepared to solve real-world design problems requiring mathematics, science, and engineering topical knowledge, whereas teachers are well prepared to design instructional environments.

COMPETENCY	ENGINEERS **ABET Criteria For Accrediting Engineering Technology Programs (2008)**	TECHNOLOGY TEACHERS **NCATE/ITEA/CTTE Program Standards Programs for the Preparation of Technology Education Teachers (2003)**
PROFESSIONAL PRACTICE	Use the techniques, skills, and modern scientific and technical tools necessary for professional practice.	Design, create, and manage learning environments that promote technological literacy. Become actively involved in professional organizations and attend professional development activities to become better prepared to teach technology education.
DESIGN AND PROBLEM SOLVING	Design and conduct experiments, and analyze and interpret data Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	Develop an understanding of design.
TEAM FUNCTIONING	Function on multidisciplinary teams.	Manage technological activities in both individual and group settings.
ETHICAL AND PROFESSIONAL RESPONSIBILITY	Understand professional and ethical responsibility.	Display a philosophy and understanding of technology education. Apply multicultural and global perspectives as they relate to the study of technology. Apply values and ethics as they relate to content issues in the study of technology.
COMMUNICATION SKILLS	Communicate effectively	Apply various marketing principles and concepts to promote technology education and the study of technology.

THE NATURE OF TECHNOLOGY AND ITS SOCIAL AND CULTURAL IMPACTS	Understand the impact of engineering solutions in a global, economic, environmental, and societal context Develop knowledge of contemporary issues.	Develop an understanding of the nature of technology within the context of the designed world. Develop an understanding of technology and society.
PROFESSIONAL GROWTH	Recognize the need for, and an ability to engage in lifelong learning.	Understand and value the importance of engaging in comprehensive and sustained professional growth to improve the teaching of technology.
CONTENT KNOWLEDGE	An appropriate mastery of the knowledge, techniques, skills and modern tools of their disciplines. **Content Proficiency.** Engineering programs require proficiency in statics, strength of materials, thermodynamics, fluid mechanics, and electric circuits. **Mathematics and Science.** Programs require proficiency in mathematics through differential equations, probability and statistics, calculus-based physics, and general chemistry. **Engineering topics.** One and one-half years of engineering topics consisting of engineering sciences and engineering design appropriate to the field of study. **Design.** Students must engage in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.	Develop an understanding of the *Designed World* **Subjects.** Areas of study in the Designed World include medical, agricultural and related biotechnologies, energy and power, information and communication, transportation, manufacturing, and construction technologies. An ability to analyze, select, use, and effectively improve technologies in Designed World contexts.
PEDAGOGICAL KNOWLEDGE		Design, implement, and evaluate curricula based upon Standards for Technological Literacy. Understand students as learners, and how commonality and diversity affect learning. Use a variety of effective teaching practices that enhance and extend learning of technology. Design, create, and manage learning environments that promote technological literacy. Follow safe practices and procedures in the use of tools and equipment.
APPLICATION OF KNOWLEDGE AND SKILLS	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Develop abilities for a technological world.

Table 1. Comparison of Professional Competencies Required for Engineers and Technology Teachers

Question 2. When it comes down to it, isn't the level of rigor such as with mathematics (i.e., calculus) one of the key components that separates the teaching of technology from the teaching of engineering due to the differences in the level of reasoning that takes place?

Response 2. You're exactly right about the mathematics. Technology teachers don't take very much mathematics or science as undergraduates. But there is a real opportunity for our teachers to make a real contribution to core disciplinary knowledge, particularly in mathematics.

Because mathematics is often taught in an algorithmic way, students question its value; and it's true that some of the mathematics that is required of students, particularly at the middle level, is not easily related to grade-appropriate contexts in other subjects. Some math, however, that is difficult for students and occurs frequently on standardized assessments can indeed be contextualized within a technology education program. And it doesn't rise to the level of calculus. It's algebra and geometry and number sense; ratio and proportion, and scale. It's a matter of our teachers first knowing what math kids are responsible for, and second, knowing how to teach it. I'll give you an example. A math assessment item that kids have real difficulty is this one:

Solve multi-step equations by combining like terms, using the distributive property, or moving variables to one side of the equation.

Note: The distributive property is an algebraic property that is used when you multiply terms within parentheses by a term outside the parentheses. As an example, 4(5 + 6) = 20 + 24 = 44 (the 4 is distributed across the terms in the parentheses). This math concept appears frequently on standardized tests.

OK, say the kids are designing an emergency shelter for victims of an air crash on a snowy mountain top where a cargo plane was carrying materials to be delivered to a home center distribution facility and these materials are now strewn around the mountain. Makes for a pretty good design problem if the kids are the four- or five-person crew that survives and they have to build a shelter that will sustain them until a rescue team that they radioed for help needs to reach them. If the shelter must be heated by the body temperature and an external heat source when the outside temperature is say, 25^{o} Fahrenheit, we have a heat flow problem that can be modeled by a simple algebraic equation.

Once the kids propose a design, they have to determine if their proposed shelter would provide an inside temperature that allows the inhabitants to be comfortable, or if they will need to make changes to their design. Guess what: The formula for heat flow involves a simple (eighth grade level) algebraic equation that specifically requires the kids *to solve multi-step equations by combining like terms, using the distributive property, or moving variables to one side of the equation.* The formula is $q = kA\,(T_i - T_o)/s$ (this is a simplified formula to find conductive heat flow) where

q= heat flow (BTU/hour)
k = thermal conductivity (BTU/hour-ft-deg F)
A = area of surface through which heat is conducted (Square Feet)
s = thickness of insulation material (Feet)
$T_{i\,=}$ Inside Temperature (Degrees F)
T_o = Outside Temperature (Degrees F)

It's not a difficult problem. It's simple algebra, but it does a great job of contextualizing a problem that causes kids a lot of difficulty. Our teachers need to be aware of the problems kids are facing, and how to present these problems in an engaging context. We admit that it's not trivial, but it's certainly within the capability of our teachers, particularly if they team up with a math colleague.

Kids also have a lot of difficulty with ratio and proportion. We've developed an activity where kids design their own bedroom and have to do math related to ratio and proportion and scale. It's in context. Kids understand the reason why they have to do the math. The math works in the service of their design.

Question 3. Is the technology teaching profession capable of raising their level of instruction to address the rigor that you suggest is needed?

Response 3. We believe so, but the key is a change in the undergraduate requirements. We've done a survey of 19 institutions that prepare technology teachers at the undergraduate level. Most require only one mathematics course of their future technology teachers and sometimes the math is a shop math course without very much rigor. A couple of schools require two courses (see Table 2). Undergraduate requirements must change if our teachers are going to address any 'engineering' content. It destroys our credibility when we claim to be teaching engineering-related material while our teachers have such a poor grounding in math.

We can do only so much with in-service professional development. It's treating the wound, not the cause. Our professoriate must make the commitment to review the teacher education programs. Our suggestion is to make it look more like an engineering education program. More math, more science, more rigorous design that relies on an understanding and an application of the math and science. It can be done, but entrenched traditionalism gets in the way.

Name of University	Math Requirement 2008
Appalachian State	One Course
Ball State	One Course
Bowling Green	Two Courses
Buffalo State	Two Courses
Brigham Young	One Course
California University of Pa.	Two Courses
College of New Jersey	Two Courses
Illinois State	One Course
Millersville	One Course
Montana State	One Course
North Carolina State	Two Courses
Ohio State	One Course
Old Dominion	Two Courses
Purdue	Two Courses
Oswego	One Course
Southwestern Oklahoma State	One Course
Stout State	Two Courses
University of Southern Maine	One Course
Virginia State	One Course

Table 2. TechEd Undergraduate Math Requirements at Selected Teacher Education Institutions

Question 4. You are conducting research to address more rigorous mathematics and science in low performing schools using technology and engineering. What are you finding and what successes or opportunities do you see?

Response 4. It's been a very interesting journey for us. We've conducted seven large-scale National Science Foundation-funded projects during the last 15 years. Much of our work has been done with teachers who teach in low performing schools. We've learned a lot. We've learned that teams of math, science, and TechEd teachers work really well together. They learn to value each other's expertise and can collaborate in meaningful ways to improve student attitudes and understanding. We've learned that design problems resonate with elementary school teachers and in one of our projects, we found that students who were engaged in integrated STEM design problems did better on 4th grade assessments in mathematics and in science than their same-school peers who were taught conventionally.

At middle level, where math scores are lowest, we're finding that students do better when they study mathematics in context. In our current NSF project (called MSTP: Math, Science, Technology Partnership), we did a pilot research study in middle school science that examined student and teacher change using teacher surveys, math content knowledge assessments adapted from NYS math and science tests, observations, and focus groups. Even with minimal direct exposure to math instruction (between four and eight hours of math instruction were embedded into 20 days of science instruction), where math was infused, students demonstrated statistically significant increased knowledge of math concepts and improved attitudes toward math. We're doing a study now that specifically looks at the efficacy of math infusion into TechEd.

One of the most important things we've learned is that design is an excellent strategy to teach math and science, but it has to be done correctly. Too often, design is a matter of students doing trial-and-error problem solving: little more than *gadgetering*.

Over the years, we've evolved a design pedagogy that we call *Informed Design* that has been developed and validated through several of our NSF projects. The difference between this method and more conventional design approaches is that informed design prompts students to acquire STEM knowledge to inform their understanding before they begin designing. To provide the foundation for informed design activity, students work through a progression of **knowledge and skill builders** (KSBs), which are short, focused activities designed to teach salient concepts and skills. The KSBs prepare students to approach the design challenge from a knowledgeable (informed) base. They also provide evidence for the teacher that can be used to assess understanding of these important ideas and skills. So, as background for design activity, KSBs enable students to reach informed design solutions, as opposed to engaging in trial-and-error problem solving where conceptual closure is often not attained.

Question 5. What are your "bigger picture" recommendations as to how our profession should proceed on a state and national level to address and take advantage of these opportunities to improve teaching and learning?

We believe that there should be an effort undertaken to develop new curriculum frameworks that reflect and respond to the STEM paradigm. One idea that has surfaced in our own conversations and in conversations with others is that TechEd programs might consider having the first two years in common with engineering programs and then becoming more focused into technological content domains. A caveat is that there should be more of a focus on analysis at the higher levels. Of course, this would require a change in the way teachers are prepared and undergraduate education might involve some courses that are taught by or team-taught with engineering faculty.

Shouldn't we also develop a national research agenda and become more research-based in our curricular decision-making and in planning instructional interventions for students and planning professional development for faculty? We think that a research agenda should be set in a STEM context where there will be increased expectations regarding research rigor. For example, experimental and comparison group teachers should be used to plan and assess the efficacy of professional development models and materials that are designed to improve student understanding.

We should encourage STEM professionals to consider teaching careers so that the TechEd workforce comprises people with backgrounds in engineering, architecture, and similar disciplines. What about the idea of a STEM certification for engineers and other STEM professionals who take lots of math, science and technology as undergraduates.

In New York, and we suspect in other states as well, there are not sufficient new graduates to replace teachers retiring from the teaching profession. It would be very beneficial if TechEd teachers took coursework that would enable them to become certified to teach in another STEM content area. This could encourage administrators to maintain, even expand, course offerings and would provide teachers who know enough STEM content to truly integrate subject matter.

Accreditation Board for Engineering and Technology. 2008. 2008-2009 Criteria for Accrediting Engineering Programs. ABET Engineering Accreditation Commission. Baltimore, MD.