The Engineering of Technology Education

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Engineering technology education (as distinguished from Engineering Technology education) is a design problem. In engineering, an important consideration is to determine the goal of the design. What is the desired result? For whom is it desirable? What are the unintended consequences? I continue to raise the question of what should the goal be for technology education. What are the design issues?

In the last few years I have become enamored with the monograph, *Understanding by Design*, by Grant Wiggins and Jay McTighe (Wiggins & McTighe, 2005). Their use of design is probably more synonymous with purpose. In this book the initial chapters are six facets of understanding - explanation, interpretation, application, other people's perspectives, empathy and self-knowledge. Then they describe a "backward design" process. The first question is "what is the goal?" The second question is "what is the evidence you will accept that the goal is achieved?" This does not mean how you obtain the evidence - but what success looks like. What will you know and be able to do if you reach the goal? Then, and only then, the third step is to develop the activities to reach the goal.

Wiggins and McTighe ask educators to determine the essential questions and keep them as goals. So what is an essential question for technology education? What I detect is that the goal technology education has set is that there should be a strand - a set of courses - in K-12 education called technology education taught by technology educators. We would know it happened when there was curriculum in technology education taught mainly by qualified technology educators. (Very few of the science and mathematics curricula have yet achieved similar quality control.) The standards, curricula and teacher professional development programs with all sorts of requirements may be thought of as activities.

Suppose I change the goal to be that students should be technologically literate - maybe fluent.

What would that mean? In a recent report by David Barlex, on developing what is being called Engineering Colleges in England - High School Academies, he states:

> "In England perception of engineering stretches from oily rag to mainframe. Much of the activity requires a sound understanding of science and mathematics but this is insufficient. Major engineering activity will not be successful unless those involved have an equally sound grasp of design, managing finance, appreciating local political and social conditions and meeting the requirements of sustainability and minimizing environmental impacts." (Barlex, 2005)

Thus, the study of engineering is not vocational; it is a way of thinking.

There is an international concern that students are not pursuing careers in science and engineering. (OECD, 2005) Engineers in the U.S. are concerned that enrollments have been dropping in engineering schools for some time and the number of new engineers is below that needed. How do students learn about engineering in our present system of schooling? For a long time engineers recruited among high school students proficient in mathematics and science because the engineering taught in good engineering schools was engineering science and not engineering practice. Engineering schools continue to recruit the science and mathematics proficient students. But in the last ten years industry has complained that the engineering students were smart and knew a lot of techniques, but they took too long to train to be useful in industry. They "lack design capability or creativity, lack understanding of manufacturing or quality processes, [have] a narrow view of engineering, weak communications skills, and little skill or experience in teamwork." (Prados, 2005) Engineers require strong technical capability, but also skills in communication and persuasion, ability to lead and work effectively as part of a team, an understanding of non-technical forces that profoundly affect engineering decisions, and a commitment to life-long learning.

For a variety of reasons the Accrediting Board for Engineering and Technology (ABET) changed the accrediting procedures for engineering programs. The new criteria (see Table 1) place strong emphasis on defining program objectives consistent with the mission of the institution and learning outcomes, i.e., the intellectual skills of the graduates. (Prados, 2005) A few years ago Douglas Gorham (Gorham, 2003) compared the new ABET criteria with the Standards for Technological Literacy and found that the standards matched very well to them. This may be due to the influence that a group of engineers appointed by the National Academy of Engineering to review the Standards had on them. However, a review of the fourteen ABET criteria also demonstrates that engineering is a way of thinking. From what we know about engaging women and minorities in learning, the broader goals are helpful. Women particularly respond to learning in meaningful contexts. It is still true that women are underrepresented in engineering schools, but there are reports that at earlier grades there is no gap between learning of boys and girls in technology education classes.

Table 1: ABET Criteria

The Accrediting Board for Engineering and Technology (ABET) criteria include abilities to:
• apply the knowledge of mathematics, science, and engineering;
• design and conduct experiments as well as analyze and interpret data;
• design a system, component, or process to meet desired needs;
• function on multidisciplinary teams;
• identify, formulate, and solve engineering problems;
• understand professional and ethical responsibility;
• communicate effectively;
• understand impact of engineering solutions in global and societal contexts;
• engage in life long learning;
• be aware of contemporary issues;
• use the techniques, skills, and modern engineering tools necessary for engineering practice; and
• manage a project.

The criteria demonstrate that engineers must be broadly educated and that linking with engineering does not narrow the choices for technology education but broadens them. The liaison strengthens technology education because now it would be connected to a discipline that has stature in both the academic and business communities. Engineering provides an intellectual base for technology education. However, the base is not without cost, since one of the major differences between technology and engineering is the use of analysis - scientific and mathematical. When ninth grade science courses become too mathematical, students complain. This may cause major issues in technology courses; but it should not. The complaint may be because students have not learned the mathematics by methods so that they can apply it in new situations. Very little attention is paid to the question of what mathematics is needed in this problem. With the emphases in Career and Technical Education on increased competency in science and mathematics, the move toward engineering in technology education also provides opportunity to gain support from this community.

One of my two major responsibilities at NSF is the Advanced Technological Education Program - technician education - not training - at the two-year college level and preparation for that in the secondary schools. The goal of the program is to increase the quality and quantity of technicians for the high performance workplace. The object is to develop technicians who have adaptive expertise. Technology education should provide the base. In fact the teacher education part of the ATE program explicitly mentions the education of technology educators. In the interest of full disclosure the most direct four-year degree route for students in this program - if that is what they want to do - is to engineering technology. So a well engineered K-12 program in technology education can lead to engineering technology education as well.

The technology education profession has worked hard on the issue of the content of its discipline and on how to be educated to teach it (ITEA, 2000); but perhaps needs to think more strategically about other dimensions like where can it get support? The present situation in schools is constrained by the accountability movement. The high stakes tests seem to drive administrators and teachers to uneducational behavior, despite the results from cognitive and learning scientists as summarized in some excellent studies by committees of the National Academies (Bransford, 1999; Pellegrino, 2001; NRC, 2002, Donovan, 2005). Some of these studies agree that authentic contexts help students learn in ways so that they can transfer the knowledge to new situations. The context helps to provide a scaffold that makes the knowledge accessible when it is useful in other situations.

Technology educators can increase the opportunities for students to become more technologically literate by collaborating with teachers in other disciplines. What is to be learned in technology or engineering laboratories has been studied by engineering educators (Feisel, 2005). They too have a long list of objectives. The NRC (NRC, 2005) is studying learning in high school science laboratories. The issues are much the same. I have conjectured that although the respective goals are inquiry and design, the methodologies are very similar (Salinger, 2003).

Working with science educators is the greatest lever for increasing instruction for technological literacy in schools. Design and technology are part of the science standards (AAAS, 1993; NRC, 1996). Applications are tolerated in the mathematics standards (NCTM, 2000). The Program for International Student Assessment (PISA) measures 15 year olds' capability in reading, mathematics and science literacy by examining one of the areas in depth every three years. The examination focuses on the ability of students to apply knowledge. As you might expect, US students did not do well in the emphasis on problem solving in mathematics in 2003 (Bybee, 2005). Yet it measures an important strength. The examination for National Assessment of Educational Progress (NAEP) is being revised and the ideas of design and technology as related to science are being discussed. Thus there is a national push for understanding design.

We are seeing more and more cooperation between developers of science instructional materials and technology educators. I would mention the development of Active Chemistry and the revision of Active Physics (http://www.its-about-time.com/htmls/ap.html) as examples; the Materials World Modules (www.materialsworldmodules.org) are another example. In each, the design of something is the assessment that the content is learned and attention is paid to the issue of design (See also the theme issue of the *Journal of Industrial Teacher Education, Vol. 39*(3), 2002). I have had conversations with a leading science educator (Krajcik, 2005) who uses as the example of an inquiry question: Can I drink the water in Honey Creek? I suggested that the question could also be: What do I have to do to the water in Honey Creek so that I can drink it? He is very intrigued. The science is the same, but my question asks for action. (Notice that there are several answers depending upon the pollutant; but also one can do something to the water at hand or one can also investigate the source of the pollution.)

As the funding for the Directorate for Education and Human Resources at NSF is being redirected, we are discussing possible new directions. We are asking how science and technology education would look if there were coherent learning progressions of content and process throughout the educational experience. For the first year, we are limiting the progressions to modeling, engineering design and inquiry in the context of content emphasized in

Table 2: Goals of Engineering Laboratory Experiences

Students should be able to:
• apply appropriate instrumentation including software tools to make measurements; • identify strengths and limitations of theoretical models; • devise an experimental approach, specifying and implementing equipment and procedures to take and interpret data to characterize engineering materials, components, or systems; • analyze and interpret data; • design, build, or assemble a part, a product, or a system; • identify and learn from unsuccessful outcomes; • demonstrate levels of independent thought, creativity, and capability in solving real world problems; and • understand impact of engineering solutions in global and societal contexts; • select, modify, and operate appropriate engineering tools.

Table 3: Laboratory Goals

Students should be able to:
• identify and deal with health, safety, and environmental issues related to technological processes; • communicate effectively about the laboratory experience in writing and orally; • work effectively in teams; • behave with highest ethical standards; and • use the human senses to gather information and to make sound judgments in formulating conclusions about real-world problems.

the standards. If the goal were to have students reach a competency with the use of design by the time they leave high school, how would instruction look in grades 2, 4, 6, 8, and 10? How are teachers successfully educated - both preservice and inservice - to deliver this kind of education?

At the elementary school, the emphasis is on reading and mathematics. I recently met with a group of people who have had success in increasing the literacy of students with science materials. They had worked on the literacy, but the science was "read about." In the discussion, I brought up the possibility of using design problems. They became enormously excited, because they had already experienced success with these kinds of problems. It then occurred to me that students are frustrated if they cannot know something because they cannot read it. But think of how annoyed they are when they cannot do something because they cannot read it. Being able to do is far more motivating. The question is can we improve reading scores through technological experiences and still be true to the technology? We had rejected an earlier proposal from this group, because the doing of science had been neglected.

Another area is after school programs. Learning through the ideas of design provides a context to learn that is very different from that in schools. The same subject matter may look very different and the students learn about design at the same time. This can be simultaneously coupled to improving reading ability. In the world of informal education, there are many opportunities for technological exhibits that provide insights into engineering experiences.

The publication of the National Academy of Engineering, Technically Speaking, provides many other excellent suggestions (Pearson, 2002). I look forward to seeing the increase in emphasis on both scientific and technological literacy with science and technology educators working together.

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