A Turn to Engineering: The Continuing Struggle of Technology Education for Legitimization as a School Subject

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Introduction

In the long march from manual training, the subject which today we call technology education has always had to contend with the question of its legitimacy as valid school knowledge. In this regard, it shares a similar history of struggle with other subjects whose initial entry into the curriculum was based on a utilitarian rather than an academic rationale. Goodson (1983) documents such cases (e.g. geography and biology) showing how in their struggle for acceptance, the primary strategy of advocates was to try to enhance the academic bona fides of their subject. He explained that utilitarian knowledge is associated with "those non-professional vocations in which the majority of people work for most of their adult life" p. 27. In one of his earliest writings in which he made the case for the subject, Calvin Woodard acknowledged its utilitarian tradition, but pointed to its intellectual side as well. He wrote:

> The word "manual" must, for the present, be the best word to distinguish that peculiar system of liberal education which recognizes the manual as well as the intellectual. Note distinctly, we do not propose to neglect nor underrate literary and scientific culture; we strive to include all the elements in just proportion. When the manual elements which are essential to liberal education are universally accepted and incorporated into American schools, the word "manual" may very properly be dropped. (Woodward, 1883, p.87).

Woodward was explaining here that the subject had to be accepted on its own terms first, before it would shed its characteristic nomenclature to please the palates of those who would be more comfortable with a name less suggestive of practical roots.

At its origins, our subject was premised upon blue-collar knowledge. The content was derived from the practices of crafts-people—blacksmiths, machinists, and cabinet-makers. The intent of early advocates was not for this knowledge to be used to reproduce the blue-collar classes that invented it, by

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teaching it to their children exclusively. Rather, it was legitimate education that would be valid for all children. John Dewey argued that manual training belonged in the elementary curriculum especially in relation to other classes of subjects (Dewey, 1901). The subject, when properly conceived, was "an inevitable and indispensable introduction to the studies of…history and geography, as the background to social endeavor" (p. 198). It could also be taught in connection with mathematics and science. He wrote that "The connection with (studies) which have to do with the symbols and forms of distinctive intellectual advance, is equally important, even if more indirect" (p. 199). Wrote Dewey, "Correlation of manual training with science is likely to be an external and artificial matter where the manual training itself is conducted for technical ends…But when it is treated as a means of organizing the powers of the child in social directions, its scope is broadened to take in salient facts of geography, physics, chemistry, botany, mathematics, etc" (p.198).

It is important to reach back to origins, for a sense of the pure intent of advocates, to establish baselines prior to trying to assess contemporary proposals for the advance of technology education. It is well to understand too that technology education is a subject still in the making (See Layton, 1994). This paper examines the phenomenon of pre-engineering as the most recent claimant to the technology education tradition. I will be arguing that pre-engineering is the latest evidence of a decided turn away from the blue-collar traditions of the field, toward white-collar academic traditions. While it constitutes an epistemological advance, pre-engineering also represents a decided sociological calculation, that hopes to make the subject more palatable to the tastes of the academics who run schools, and the middle and upper classes, whose children turn away from the base subject after the compulsory stages in the middle grades, as they fix their attention on the college track, and upon professional careers. The rest of the paper is organized as follows (a) What is pre-engineering? (b) How widespread is the practice of pre-engineering? (c) Why has pre-engineering become a prominent idea? (d) "Regular" pre-engineering (including the case of Massachusetts) (e) Pre-engineering and the universities, and (f) Reflection and conclusions.

What is Pre-engineering?

Pre-engineering in this paper means coursework or subjects that draw content from the work of engineers, and that promise engineering careers as likely futures of the students who pursue them. For purposes of this paper, four conceptions of pre-engineering must be identified, (a) pre-engineering in *career academies*, and (b) pre-engineering in magnet schools, (c) pre-engineering *regular,* and (e) pre-engineering *the movement*.

Career Academy Conception

Career academies began in 1969 in Philadelphia, when an electrical academy was started at Edison High School supported by a Philadelphia electrical power company. They have become an important part of the school

reform movement, offering an alternative conception of how schools might be organized. Since the early beginnings, the academy model has spread to several states, notably California, Illinois, New York, and Maryland, and including Florida and Hawaii. These schools focus upon particular careers, including automotive, finance, law, aviation, and computing. Scott Griffith (personal communication), lead technology education consultant for California informed this author that pre-engineering is a focus in his state. He cited aerospace academies as an example. Stern, Dayton & Raby (1998) pointed out that in 1998 the total number of academies nationwide may have reached 3000. They explained that career academies "combine a college preparatory curriculum with a career theme" and that "Academic courses that meet high school graduation and college preparatory requirements are linked with technical courses that focus on the academy's field of work" (p. 4). Academies are intended to bridge the gap between academic and vocational education. Programs prepare students both for two and four-year colleges. One healthy aspect of the career academy movement is that it has been the basis of evaluative studies (e.g. Kemple, 1997; Linneham, 1996) that add an empirical dimension to discourse on their efficacy.

Magnet School Conception

Magnet schools are district-wide specialty schools, which emerged in the 1970s as a means of desegregating school systems. One of the incentives for parents to send their kids to these racially mixed schools was the prospect of exposure to innovative curricula. One curricular approach is to focus schools around particular themes. Among themes that one finds via electronic searches of this topic are: "Technology/Engineering/Computers" and "Careers/Vocational: General and Specific. A large number of magnet schools seem to be organized around these themes. In both categories, there are schools with a pre-engineering focus (see Magnet Schools of America, 2002).

In a paper presented at the ITEA conference of 1990, Gary Stewardson alerted the field to the possibilities of magnet schools for the purveyance of technology education. He reported on the curriculum of one school, namely the Thomas Jefferson High School for Science and Technology, in Fairfax County, Virginia. He explained that the mission of the school was to "stimulate excellence in mathematics, science, and technology education." The school had eleven technology laboratories, including Energy, Power, and Engineering; Chemical Analysis; Telecommunication; TV Studio; Biotechnology; Industrial Automation and Robotics; Computer Science, and Microelectronics. The pre-engineering credentials of this school are clear. Stewardson saw the possibilities for the field and issued the following entreaty:

> The trend in the development of specialized schools in the areas of
> mathematics, science and technology is very real. The involvement of
> technology education in these schools has been minimal at best. The
> advantages to the technology education teaching profession as well as to the
> students in these programs are also very real. As technology education
> teachers, we need to become involved. (Stewardson, 1990).

Regular Conception

The regular conception of pre-engineering speaks of the disposition of the subject itself as it continues to metamorphose. There is abundant evidence that in its latest manifestation, leaders view technology education as drawing inspiration from the discipline of engineering, and the practice of engineers. This is a conception that sits well with the National Science Foundation (NSF). Indeed, Gerhard Salinger, technology education Program Director at the NSF, has lately been asking this author to explain the difference between technology education and engineering! As the subject has sought to position itself thus, "design" and "problem-solving" have become the anchoring ideas for curriculum as well as instruction. More recently, the idea of "trade-offs" has become prominent, as members of the engineering community who have joined the discourse on technological literacy have begun to infuse it with their own ways of thought. Pearson & Young (2002) of the National Academy of Engineering write that one characteristic of a technologically literate citizen is that he/she "Understands basic engineering concepts and terms, such as systems, constraints and trade-offs." In the history of this field, one can search long and hard, even through the halcyon years of the great curriculum projects, and not find the term "trade-offs" as a concept to be taught. That has now changed now with the entry of the engineers (see for example Benenson [2001] in which the author, an engineer, discusses how everyday objects such as shopping bags can be used in the classroom to teach powerful design concepts). Later in this paper, a fuller discussion of the regular conception of pre-engineering will be developed.

Movement conception

The movement conception of pre-engineering is so called here, because it reflects a current wave of interest. Leaders of technology education are debating whether or not this is a wave worth catching. This version of pre-engineering can be defined as a course sequence option that sets the stage for possible enrollment in engineering programs in two and four-year colleges, upon graduation from high school. Typically, the course sequence is comprised of three key components, namely, mathematics, science, and technology education, with strong emphasis on engineering careers. This version of pre-engineering is premised not so much on within-subject change, as does the regular version, but rather on the nature of the company the subject keeps in the curriculum.

Two prominent *movement* versions of pre-engineering are evident from a national scan, namely the *Project Lead The Way* model (PLTW) and the so-called "Stony Brook" model, derived from the seminal work by Thomas T. Liao and his colleagues at the State University of New York at Stony Brook. Both models are premised upon the three common features described above. At the high school level, Project Lead The Way offers three course-sequence options from grades 9 to 12. Over the four years, students choose from six "engineering" courses (namely, Introduction to Engineering, Principles of Engineering, Digital Electronics, Digital Lab, Computer Integrated

Manufacturing, and Engineering Design and Development. In each year they take an engineering course, along with Mathematics, Science, English, Social Studies, Physical education, and (except for grade 12) a foreign language. The course Principles of Engineering is exploratory in nature, and is intended to help students learn about engineering careers, by understanding what engineers and technicians do, and how they use math and science (see http://www.pltw.org). The middle school features a four-course sequence called Gateway to Technology, inclusive of Design and Modeling, The Magic of Electrons, The Science of Technology, and Automation and Robotics.

The "Stony Brook" model is observable in the engineering program at Madison West High School in Wisconsin, identified by Len Sterry of the ITEA as an exemplary program (See http://imagine101.com). The program is led by teacher Alan Gomez. Like Project Lead The Way, it too features four-year course-sequence options (engineering or architecture). Both feature a common set of mathematics and science courses. Technical courses vary with focus. Engineering students take Materials Science, Design Drafting, and Engineering I, II and III. Architectural students take Design/Drafting/CAD; Construction, Advanced Architecture, and Independent Study in Architecture. The mathematics courses students will take over the four years include Accelerated Geometry, pre-calculus, calculus I and calculus II. Science courses include biology, chemistry, and physics. The curriculum includes an "engineering careers" aspect that requires students to research and prepare a written report on an engineering career of interest. It also includes a set of case studies that are problem solving challenges. Included among the cases at Madison West High School are Super-Mileage (design of a super mileage vehicle), Careers (investigation of engineering careers), and Ethics (inquiry into ethical practices in engineering). (see Gomez, 2001)

How Widespread is the Practice of Pre-engineering?

To help answer the question just how widespread is pre-engineering in technology education, this author made telephone calls to several State Supervisors for technology. Invariably, it was the movement version of the subject that was on the minds of these supervisors. They were asked whether pre-engineering was an aspect of their state curriculum approach to technology education, and to what extent had the idea made its way into their schools. The Table 1 helps capture what could be gleaned from supervisors who were available for conversation.

The round of telephone conversations with state supervisors (as summarized in Table 1) revealed that the movement conception of pre-engineering is taking root on a broad front. It was clear that Project Lead The Way programs were ubiquitous, operating in synchrony with regular technology education in some states (e.g., Texas, Indiana, Connecticut, and Michigan), and independent of technology education in others. In Indiana and Texas, coursework taken in PLTW counts as technology education credit.

Table 1
Status of Pre-engineering in Selected States

State	Status
Alaska	Some districts have a pre-engineering focus, aligned to graduation and occupational standards.
Arkansas	Pre-engineering is one of three programs of study in careers. The focus is not just on pre-engineering but also pre-technician. Four high schools and one middle school have Project Lead The Way (PLTW) state.
California	Pre-Engineering standards have been developed for grades 9-12. Some schools have pre-engineering Career academies (e.g. in aerospace).
Colorado	Pre-Engineering seen as complimentary to technology education in the upper grades. Higher Education Advance Technology (HEAT) Center a partner in PLTW, which is in an "early adopter".
Connecticut	Heavy PLTW state, the program being in 16 school districts, with University of New Haven being a PLTW training site.
Delaware	Diverse technology Education programs, from Industrial Arts to pre-engineering. One PLTW program in a vocational high school.
Georgia	Pre-Engineering on the books for 12 years in the state. It is available in the high school upper grades in the form of three courses—Intro to technology, Design and Electronics. PLTW in 8 school districts (out of 180).
Hawaii	Member of High Schools That Work (HSTW) network which has endorsed PLTW.
Illinois	Pre-engineering not in the state curriculum.
Indiana	Strong PLTW state. Program in 20 school districts with another 100 considering adaptation. Of these 40 would come aboard in a year. The state superintendent (who is on the PLTW board) wants 40% of schools to adopt it. Superintendent got the state to accept PLTW courses as technology education courses. Courses are college preparatory. Purdue University a driving force.
Kentucky	Working with CATTS. One pre-engineering course. Six PLTW sites in state. PLTW articulated with engineering schools.

Table 1 (continued)
Status of Pre-engineering in Selected States

Massachusetts	Strong engineering focus in technology education, especially noticeable in the state curriculum guide, called "Science and Technology/Engineering Framework". Tufts university engineering school strongly influences the technology education curriculum. Five PLTW high schools.
Michigan	Pre-Engineering observable within career pathways (engineering, manufacturing, Industrial Technology). PLTW in both middle and High Schools (35 schools committed). Ferris State is Official PLTW training center.
Minnesota	Strong super-mileage vehicle focus in the curriculum. Five PLTW schools.
New York	Has had a course called "Principles of Engineering since the late 1980s. State does not endorse specific programs but recognizes PLTW as viable alternative for some students. State view is that technology education should be "broad-based with strands that offer students as many options in technology as possible…"
Oklahoma	State standards reflect pre-engineering in grades 6-12. Pre-engineering a feature of the curriculum of Tech-Centers (grades 11 & 12) and in area schools. There are 3 PLTW schools.
Texas	Engineering reflected in the 9-12 curriculum through traditional tech Ed courses, but also through a course titled "Engineering Principles" that focuses on principles and practices that underlie engineering careers. PLTW courses (Intro to Engineering Design, Digital Electronics, Principles of Engineering, Computer Integrated Manufacturing and Engineering Design and Development are designated Texas technology education courses. Both high school and middle school programs are evident. Middle school Gateway to Technology curriculum includes "design and Modeling" "The magic of Electrons" and "The science of Technology".
Utah	In the high schools "Applied Technology" includes T&I, IT and Tech Ed. Pre-Engineering is a way to avoid redundancy between these. PLTW is one pre-engineering approach. Another is the "Utah Plan" comprised of a 4-course sequence, namely Foundations of Technology, Principles of Technology, Engineering, and Design.
Wisconsin	"Stony Brook" approach to pre-engineering in about 8-10 programs. Madison West High school a model.

In one state where PLTW is entrenched, one comment heard was that with respect to the state's technology education program, it was "the tail wagging the dog." Three states (Massachusetss, Utah, and Wisconsin) now include "engineering" in the official name of the subject.

Why Has Pre-engineering Become a Prominent Idea?

The rationale for pre-engineering is multi-faceted. One source of impetus clearly is the feeling in the engineering community that the pool of students who are interested in such careers is becoming shallow. It is clear that the Project Lead The Way program responds to this need, through the dictates of an endowment, which intends to encourage more high school students to consider engineering careers. Schools of engineering (such as Purdue) are interested in pre-engineering because of its recruiting possibilities. Pre-engineering could be a pipeline from high school to their programs.

Another rationale is that technology education programs are vulnerable beyond the middle grades, where courses become elective, and where states may exclude the subject altogether from high school graduation requirements. Our curriculum conceptions have never really been able to flesh out a coherent progression of ideas that could inform a program in grades 9-12. Pre-engineering provides a way to give technology education legitimacy and life in these grades.

Yet another rationale for pre-engineering is that the standards movement, and increasing pressure on schools to have their students meet normative academic criteria, places subjects perceived to be non-academic at risk. Technology education bears the non-academic mantle, and in such a climate, is better off being tied in a bundle with high value subjects (such as mathematics and science). Scott Griffith, technology education consultant for California communicated with this author thus:

> California is focused around the more traditional standards of math, science, etc. than on career and technical areas. Our state has all but eliminated industrial technology education and we are trying to use pre-engineering as a new direction of bringing relevance and application to an otherwise academic-only system. (Griffith, Personal Communication).

Where pre-engineering is linked to career academies, the rationale is not special to technology education, but rather emanates from the tensions that gave rise to that movement, such as the reform of urban schools, and the quest to integrate academic and career education. While the current *movement* models do not have their origins in career (vocational) education, clearly the idea of linking technology education to engineering careers would be recognized by the vocationalist community as desirable curriculum practice in keeping with the new vocationalism (e.g. Grubb, 1996). Elsewhere this author has written about the need for the field to accommodate curricular border crossings, across academic and vocational lines (Lewis, 1996).

The rationales for pre-engineering provided thus far are located outside of the field. That is, pressures and tensions in the external environment cause the

professionals within technology education to search for ways to continue to exist. But a primary argument of this paper is that there is a deeper internal rationale for the turn to engineering that is imposed by the field itself. This rationale requires first a sense of the history of the field, and the social and epistemological forces that conspire to cause advocates to be continually seeking ways to legitimize it. It cannot be seriously argued that a subject that could point to origins in the American curriculum dating back to the 1870s is in need of being recognized still. What technology education advocates mean when they say this is that the subject needs to be recognized on *our* terms. The appeal of engineering is that it offers the chance of pushing the field away form its blue-collar roots toward white collar acceptability. And if we look not at the movement versions of pre-engineering, but rather toward the regular version, which is technology education as it stands today, we would be able to discern the tendency.

"Regular" Pre-engineering - Including the Case of Massachusetts

As indicated above, *regular* pre-engineering speaks to the current nature of technology education itself. Though often by proxy, engineering has been central to curriculum thinking in the field since Warner's path-breaking presentation in 1947, proposing that the content of industrial arts should reflect the technology (see Warner, 1965). Manufacturing, construction, transportation, communication, power and energy, and management, included among Warner's curriculum categories, are all contexts in which engineers do their work. In his seminal doctoral thesis that elaborated Warner's presentation, Delmar Olson invariably included engineering as a representative curriculum component. For the transportation industries he included mathematics, engineering, chemistry and physics as representatives of associated occupations and fields. Among "representative curriculum components" for these industries he included Research, Invention, Design, Experiment, Engineering, and Testing (Olson, 1957, p.150).

Because so much was new in what Warner, then Olson, were proposing as curriculum directions for the field, engineering had to lay fallow, as manufacturing, construction, transportation, power and energy, and communications took hold. From the 1960s through the 1980s, when the great curriculum conceptions (Industrial Arts Curriculum Project, American Industry, Orchestrated Systems, Technology, Maryland Plan, etc) held sway, either directly or indirectly, the focus had been on replacing woods, metals and drafting with larger organizers that were more representative of the technologies of *industry*. By the end of the 1980s, the new content organizers had become commonplace, pushed not just by curricular advocacy but by new modular laboratory designs. The field at this point made a decided shift on two fronts, both having pre-engineering resonances; first, it changed emphasis from a disciplinary-based curriculum focus to a process focus, and second, it started an active courtship with important science and engineering bodies.

Courtship with Science and Engineering

On the courtship side, the field forged alliances in turn with the American Association for the Advancement of Science (AAAS), National Aeronautics and Space Administration (NASA), the National Academy of Engineering (NAE), Institute of Electrical and Electronics Engineers (IEEE), and the National Science Foundation (NSF). The opening might have been the publication of Project 2061 report on technology (Johnson, 1989) by the AAAS, and their inclusion of technology (the designed world) as an organizer for what all Americans should know when they study *science* (American Association for the Advancement of Science, 1990). Responding to the fact that a prestigious scientific body had now embraced technology on terms that were agreeable to the field, a prominent voice in the technology education community proposed active courtship with science for recognition purposes (see Bensen & Bensen, 1993).

NASA and the NSF co-funded Technology for All Americans (International Technology Education Association, 1996) and the new standards for technological literacy (International Technology Education Association, 2000). Reflecting on the entry of NSF and NASA into the funding picture, Dugger (1994) proposed an approach to the subject that involved the integration of technology, science, engineering and mathematics. He argued "The technology education profession must work closely with the science, engineering, and mathematics professions to assure that technology is placed in the school curriculum as a required subject" (p. 22). Indeed, beyond the better known projects cited above, there has now been an accumulation of NSF funded projects, all with a science-math-technology integration theme, and with technological problem solving and design being key pedagogical aspects (e.g. Benenson & Piggott, in press; Burghardt & Hacker, in press; Copeland & Gray, in press; La Porte & Sanders, 1993; Hutchinson, in press; Satchwell & Loepp, in press; and Kolodner, in press). Some of these projects have focused on the development of curriculum materials with children in mind. Others have focused upon the professional development of teachers.

Beyond these projects, the NSF has been providing incentive for the engineering and education communities to collaborate. A recent example of this is that the Engineering Directorate has started reaching out to the education community, through a new "bridges" grants program that encourages engineering/education collaboration. The technology education program at University of Georgia has been successful in obtaining a planning grant in this program, for a project that creates engineering-related curriculum for high achieving high-school students, and which brings technology and engineering faculty at the university together (Wicklein & Hill, personal communication). Another grant was awarded to Virginia Tech with Mark Sanders from the Technology Education Program serving as co-principal investigator.

The publication *Technically Speaking* is the result of special NSF funding (see National Academy of Engineering, 2002). In this document, the result of collaboration with prominent technology educators, the Academy resonates with

the field's focus on technological literacy, adding its considerable voice to this effort. In like manner, members of the IEEE (Institute of Electrical and Electronic Engineers) published *Technological Literacy Counts*, proceedings from a remarkable conference of Deans of Colleges of Education and Colleges of Engineering, in which the ITEA played a significant role, and in which prominent technology educators both from the U.S. and elsewhere were invited presenters. Throughout this document the primary sentiment is that engineers and educators must bring their two cultures together to work towards the goal of making students technologically literate (see Institute of Electrical and Electronics Engineers, 1998). A key entity in these ventures by the IEEE and NAE, has been the International Technology Education Association. ITEA has been copiously funded by the NSF and is recognized by all of these major scientific bodies as their primary link with schools in the quest for purveying pre-engineering knowledge. It is not coincidental, that the foreword of the new standards for the subject is written by William Wulf, in his capacity as President of the National Academy of Engineers (see International Technology Education Association, 2000).

Process approach

On the process side, the second Jackson's Mill group arrived at "the Technological Method" as framework for curriculum (Savage & Sterry, 1990). Content became but one aspect of this method. This process approach could also be attributed to strengthening cross-national ties, particular with British technology educators. The British approach had long gone the process route, and in the mid-1990s the subject Design and Technology was mandated for all grade levels (see Department for Education, 1995). The new approach pushed design and problem solving to the forefront of both curricular and pedagogical thought (e.g. Custer, 1995; Hatch, 1988). The new *Standards for Technological Literacy* (International Technology Education Association, 2000) includes two chapters on design. Authors separate themselves from the traditional conception of design held by the field, indicating that "Designing in technology differs significantly from designing in art" (p.90). They continue that "Technological designers…*such as engineers* (emphasis added) are concerned with the usability and desirability of a product or system." (p. 90). There has been some tension in the literature as to how much should the pedagogical focus be bounded by these ideas. One critique has been against the tendency to view problem-solving and design in a formulaic way. Another is that problem solving and design should not be the only methods of the field (see Chidgey, 1994, Lewis, Petrina & Hill, 1998; McCormick, R., Murphy, P., & Hennessy, 1994; Williams, 2000).

An encouraging aspect of the design and problem solving push is that around the question of children's understanding of mechanisms and structures; it has yielded one area of technology education where a programmatic line of research is evident (e.g. Gustafson & Rowell, 1998; Gustafson, Rowell & Rose, 2001; Gustafson, Rowell & Guilbert, 2000; Parkinson, 1999, 2001; Rogers & Wallace 2000).

Several things are significant here. First, much of this work is done outside of the U.S.—in Australia, Canada, and the United Kingdom. Second, the focus is upon elementary school children. The importance of technology education at this level is that it is gender neutral. Girls get exposure to engineering ideas and to engineering careers at an early stage. In their on-going studies, Rowell and colleagues at the University of Alberta bring engineers to elementary classrooms to work with children and their teachers on problem solving and design problems (see Rowell, Gustafson & Guilbert, 1999).

Regular Pre-engineering in Massachusetts—A Case in Point

It is being argued here, that technology education the subject has taken a decided turn to engineering, in its regular progression. An illustration of the advance that has been made here, and what the future might look like at the state level, can be discerned from examination of the Massachusetts technology education curriculum guide (see Massachusetts Department of Education, 2001). The first striking aspect of how the subject is viewed in Massachusetts is that it is called "Technology/Engineering."

This is independent of the influence of any movement version of pre-engineering. The conception of the subject in the Massachusetts is strongly influenced by engineering faculty from the School of Engineering at Tufts University (notably Ioannis Miaoulis, Peter Wong and Martha Cyr). The State curriculum framework shows how science, engineering, and technology can intersect. It examines the unique natures of science and technology, as well as complementarities between them. The authors explain that:

> Technology/Engineering works with science to expand our capacity to understand the world. For example, scientists and engineers apply scientific knowledge of light to develop lasers and fiber optic technologies and other technologies in medical imaging. (p. 71)

In similar vein it is explained that:

> In some of the most sophisticated efforts of scientists and engineers, the boundaries are so blurred that the designed device allows us to discern heretofore unnoticed patterns while accounting for those patterns makes it possible to continue to develop the device. In these instances, scientists and engineers are engaged together in extending knowledge. (p. 4)

Throughout the grades, the curriculum guide takes an engineering slant. In grades 3-5, students learn about tools and materials, and are expected to display "engineering design skill" by finding and proposing solutions to problems, working with a variety of tools and materials. In grades 6-8, students are expected to "pursue engineering questions and technological solutions that emphasize research and problem solving" (p. 72). In the grades 9 and 10 they take a full year technology/engineering course covering engineering design; construction technologies; power and energy technologies in fluid, thermal and electrical systems; communication technologies; and manufacturing technologies. In grades 11 and 12 students can take advanced courses such as automation and robotics, multimedia, and biotechnology. At this level there is a

strong engineering careers focus, with course sequences available for students intending to pursue engineering programs at the college level.

This Massachusetts curriculum plan for technology education is path-breaking. Here is a state that has deliberately conceived of the subject as a derivative of engineering and has framed it in tight connection with science. Technology education is conceived not as an outlier but as high-status knowledge. The subject is able to make this advance because the advocates for it are engineers.

Pre-engineering and the Universities

To what extent is pre-engineering influencing teacher education programs at the universities? As indicated above, the PLTW program has an important in-service requirement, which is conducted at universities that are partners in this project. These universities include Ferris State, Purdue, and University of New Haven, and possibly others. It is conceivable that the technology teacher education curriculum in these institutions, to the extent that they are viable, would be influenced by the PLTW-focused curriculum agenda. Several universities have received technology education-based awards from the NSF in the past decade (e.g. Illinois State, Hofstra, North Carolina State University, College of New Jersey, City College of New York, Virginia Tech, University of Maryland - Eastern Shore, and Georgia Tech). The University of Georgia's recent successful planning grant has been mentioned above. And this year, a consortium of seven universities led by The Ohio State University and University of Minnesota, and inclusive of the University of Georgia, Colorado State, University of Wisconsin-Stout, Eastern Michigan University, and Purdue University, received an award based on a proposal for creating teacher-education instructional and curriculum materials based on the standards. An aspect of this project will be to develop design and problem-solving pedagogical materials. These awards all push in the direction of a process-approach to technology education, invariably focusing upon design and problem-solving. Some, like Illinois State's IMAST project, focus upon math/science/technology integration.

Beyond awards, some university programs have taken on a pre-engineering disposition, merely because of their local situations. At Ohio State for example, the old Industrial Technology Department is no longer autonomous, being pushed into merger with other teacher education units in their College of Education. That merger has given rise to a collaborative Math/Science/Technology approach to teacher education licensure. Some teacher education programs are housed in Colleges of Engineering (e.g., Brigham Young), or in Schools of Technology (e.g. Purdue and Iowa State). In such cases, the programs can't help but be influenced strongly by an engineering ethic.

However, at the normative level, where the center or heart of technology teacher education might lie, whether it be at a big-producer institution such as the University of Wisconsin - Stout or at smaller teacher-producing institutions,

one would conjecture that the influence of the process trend is being strongly reflected, and that design and problem solving are ubiquitous features of the curriculum.

What are we to make of schools that are not engaged in technology teacher education, but yet are engaged in funded works that relate to the field? Invariably, the project leaders from these schools are scientists (e.g. Janet Kolodner and David Crismond of Georgia Tech), or engineers (e.g. David Burghardt of Hofstra, and Gary Benenson of City College of New York). Because of their backgrounds, these scholars bring fresh new insight regarding possibilities for technology curriculum and instruction, and collaboration with them makes engineering seem not so distant a notion about which technology educators should be pre-occupied.

Reflection and Conclusions

Where would the current preoccupation with engineering lead?   And is this new preoccupation a bright prospect for the field? Charles Bennett, founder of the Mississippi Valley Conference, cautioned once that "…we should not be turned aside by each new thing that appears. It is to be expected that there will be some chaff to be blown from each year's crop of grain" (Bennett, 1914, p.15). As we consider the notion of pre-engineering this is a caution that is appropriate now. It is the view of this author that pre-engineering is an instructive movement for technology education, with long lasting possibilities, *where it emanates from a regular, as opposed to a movement conception*.

This is not to discount the value of movement conceptions of pre-engineering, such as Project Lead The Way. Programs of this order help push the subject beyond its normal bounds, by making it acceptable as high status knowledge. Further, this approach to technology education fills the void in the progression of the subject in schools that occurs in the high school grades. The focus on careers of PLTW and the Stony Brook model is quite sensible, and unmasks the folly that technology education must respond to a pure liberal impetus, and shun vocationalist connections. There is evidence that school programs can make a difference in students' choice of scientific and engineering careers (Woolnough, et al, 1997), and for this reason alone programs such as Project Lead The Way cannot be discounted.

But while it is an advance of sorts to become able to figure in permutations with high status subjects such as science and mathematics, and by proxy to be associated with engineering, mainly the gain of movement versions of pre-engineering will be on the sociological front, and not on the epistemological front. The beneficiaries are those students who are already highly motivated, and for whom college is a natural next stage after high school. This is the gain. But a caution is needed here, in case the PLTW money bubble bursts, and the subject has to return to its long standing clientele, many of whom are closer to the center of academic performance.

I feel that pre-engineering in its regular dimension has greater long term promise. The reasoning here is that this version of pre-engineering argues the

case for the intrinsic worth of the subject, not just in permutations with other high status subjects, but in its own right. It represents an organic advance within the subject—a new stage in its metamorphosis. What makes this version of pre-engineering important on epistemological grounds, is that the subject is argued on its own terms. Problem posing, problem solving, design, and making, are what make the subject pre-engineering – not being packaged with math or science. This is what makes the Massachusetts case so important, because here technology education becomes engineering, and not just in the high school grades, but all the way from pre-kindergarten up. The subject is accepted on its own terms, and then its important relationships with science and mathematics are exploited.

The idea of "Technology for all Americans," is a democratic one. But technology education has difficulties on this score since the subject is still largely male-centered. A pre-engineering approach that starts in pre-kindergarten is more likely to democratize the subject than one which starts later. It is quite possible that because of successes in technology education, some students, who ordinarily might be intimidated by high status subjects, would now venture to take such subjects. The most powerful work of the subject remains that which it does among the children of the masses.

It is well to remember that while engineering careers are a logical extension of the pursuit of the subject in school, it is not the only logical extension. While the careers focus is sensible, technology education still has as its major purpose the inculcation of technological literacy, and in fulfilling this purpose, the subjects with which the subject should partner in the curriculum ought not to be limited merely to those in a career trajectory. Foster (1995) reminded us that, close to its origins, the subject was conceived as social study. Indeed, this was the vein in which Dewey perceived it. Woodward was clear on its multi-faceted rationale. In providing evidence of the post-graduation pursuits of students of the St. Louis manual Training school, he reported that "Of 239 graduates … representing about 500 students entering the school, 87 have gone into higher education in the line of the professions or teaching. The professions are law, more often medicine, dentistry and surgery, and still more often architecture and engineering" (p. 74).

That was of course another time, but the essential notion remains, that study of technology education ought to lead to multiple ends. This very important fact is a caution that while the subject may derive from engineering, the many roads that could lead from it are a strong argument against it becoming pre-anything. Sanders & Binderup (2000) provide several illustrations of how the subject intersects with non-technical subjects in the curriculum, including the social sciences. These intersections can lead to a host of careers, far beyond engineering.

The turn to engineering for the field of technology education is a turn away from knowledge premised upon blue collar craft traditions, toward that premised upon white-collar professional traditions. In making this turn, what should the field leave behind? It is true that in today's workplace, distinctions between

classes of workers have become blurred, and that technology has decimated many traditional crafts. But when this author stands at a construction site, he sees a continuum of workers, from those installing air-conditioning infrastructure, to welders, carpenters, brick-layers, crane-operators, and engineers. They all are engaged in putting the pieces of an engineering puzzle together and they are all interdependent. There is a danger in conceiving the subject as pre-engineering, and in our desire to have it become more acceptable as valid school knowledge, we may take ourselves too seriously, throwing out those aspects of engineering that remind us of our humble practical traditions, and keeping only those aspects that resonate with the dominant academic ideology of schools. Pre-engineering has to mean the full range of engineering knowledge, reflective of the full range of engineering careers in which citizens representative of all of the social classes engage.

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