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Contents

From the Editor

Articles

Editorial

Miscellany

From the Editor

Procedural Knowledge, Storm Doors, and Ragged Edges of Metal

A lot of the products we purchase require assembly once we take them out of the box. I have noticed that some people lay out all the parts and then try to put the product together, without reading the instructions. Others sit down and read through the instructions first, examine the parts, and then proceed. Yet others read the first step in the instructions, carry out that step, read the next step, and so on. There are probably other possibilities as well. My approach generally follows the second description.

I recently purchased a storm door. It came with a rather voluminous installation booklet. I read through the booklet, laid out the parts, and began. The hinges were to be attached to the door with sheet metal screws. In looking at the screws provided, the thickness of the metal into which they were to be threaded, and the diameter of the pilot hole, I decided that there was going to be trouble ahead. There was. I ruined the Phillips head on three of the screws. Knowing that steel and aluminum were dissimilar metals and could cause deteriorating electrolysis, I fretted about what kind of screw I should purchase to replace the originals.

With the hinges attached, I proceeded with the installation. I then discovered that the door would not clear the header piece. I went back to the instruction booklet and discovered that I had misinterpreted the procedural steps. Uncharacteristically, I had followed the words rather than the drawing. Three more broken screws, another trip to the home center, and I had it installed properly.

My neighbors know what I do. I have talked to them about the importance of developing technological literacy and problem solving skills, as well as my role in doing that. They also know that I was educated in an earlier era, in which I had developed a considerable amount of skill in the use of tools. My pride was devastated, for I was certain that my neighbors saw me install the door, remove it, then install it again. They knew that I had made a mistake. I considered doing the reinstallation after dark, when my neighborhood had gone to bed.

Then came the installation of the latch set. The manufacturer recommended the use of a wood cutting spade bit to cut through the thin aluminum sheet metal for the latch, to me an obvious example of misusing a tool. I knew what would happen if the spade bit was dull, so I sharpened it. Just the same, it produced a ragged looking hole. Though it ended up being covered by the latch assembly, I will always be able to recall what it looks like under there and that will bother me.

What should have been a rather straight-forward and rewarding installation, ended up being a complex, philosophical, and somewhat frustrating experience. I wondered if the do-it-yourself era has passed the average do-it-yourselfer. I also wondered if knowing what I know about materials and processes actually resulted in more anxiety about the job than would have been the case with the "average" homeowner.

When I started my early morning class the next day, I found a role reversal. I had prepared what I thought was an excellent, step-by-step procedure for setting up and using a computer-controlled router in the lab in which I teach. Yet, when I put it to use with students, I found that it fell short in several ways. For example, I discovered that there should be only one discrete instruction per written list item. Otherwise, students tend to overlook the later-occurring instructions in the item. They also tend to skip steps, especially when the list of steps is long. When I asked the students why they did not read the steps thoroughly, the answers they give were varied and did not lead me to any conclusions. What's more, when I asked those who had successfully gotten the computer-controlled router to perform properly, few had any idea of the concepts behind the procedural knowledge. They had little or no idea why the steps were performed, nor why they were performed in a particular order. They followed the steps like robots. I should have known this at the outset, for I had already reinvented these wheels or turned over these rocks many times before.

The reason for teaching the students how to use the router was to enable them to incorporate it into the process of solving technological problems. Yet using it demanded the following of prescribed steps and any departure from these steps would result in frustration for the students or even damage to the machine. Though the machine could be applied in creative ways, the actual use of the machine to achieve this creativity is rather routine. How to teach this sort of underlying procedural knowledge, when to teach it, and to what depth to teach it, has been a career long dilemma for me, and I am certain I am not alone. In earlier days, we could justify teaching to nearly any depth we wished, for one of the primary objectives was to teach skill in the use of tools. Those days are gone.

Consider two polar scenarios related to the foregoing—scenarios that I have described in the past. One is in teaching students about structures. Students might be given a set of materials, prescribed in a design brief, to build a structure that would hold the greatest amount of weight. In many situations I have observed in educational practice, the students are given little or no background instruction regarding how to solve the problem. In fact, they are expected to solve the problem with the knowledge with which they walked through the door to the class the day the problem was introduced. No explanation or experiences are provided to the student about how forces might be distributed, how gravity might interact with the structure, nor how the properties of the materials being used might determine the ultimate strength.

Once the structure is tested to determine how much weight it could hold, the results can often lead to erroneous conclusions by the students. For example, the elapsed time from when glue was applied to two pieces of material, and when the pieces were assembled, may have actually accounted for why the structure failed or did not fail, rather than the design itself. Likewise, a student who has the manual dexterity and skill in the use of hand tools will be able to create closer fitting joints than those who do not. The precision with which the structural members fit with one another may have been more important than the design. We may be inadvertently teaching "bad technology," akin to the misconceptions that result from "bad science" about which the science education community has been concerned for the past several decades. Students may have made cause-effect conclusions based upon the incorrect cause.

At the other extreme is the insistence that students learn so much prerequisite procedural knowledge and theory about a particular area of study that only a few can invest the calendar time necessary to enable them to solve technological problems. Others lose interest and give up.

One example of this scenario is in the area of electronics. Students of this subject often spend great amounts of time learning Ohm's Law and verifying its truth using power supplies and meters. They learn about alternating and direct current and how to convert the former into the latter. They learn about resistor color codes, and capacitive reactance. Too often, though, they may never reach the point where they can solve a technological problem using electronics unless they earn a degree in the subject.

Electronic experiment kits, intended primarily for elementary/middle school students, are available from Radio Shack and a variety of other sources. They come with a booklet that illustrates and describes how to connect an array of different electronic circuits—procedural knowledge. Though the children assembling these circuits likely have no idea of how they work, motivation comes from the practical application and the appeal to their senses. They connect a circuit for a buzzer that operates from a pushbutton switch. They connect a circuit that turns on a light when the room becomes dark. By combining the two, they can intuitively put together a circuit that turns on a buzzer (instead of a light) when the room becomes dark. They have solved a technological problem that they wanted to solve, and along with it came the excitement and motivation with which all of us in this field are familiar and uniquely bestowed. With guidance and more experience, the learner often becomes curious about how the circuit works. Practical application begets curiosity about the underlying theory.

I had roughed out this manuscript to this point and then I left town to participate in the annual conference of the Technology Education Association of Pennsylvania. Coincidentally, one of the keynote speakers at the conference was Iannois Mialoulis, President and Director of the Boston Museum of Science and former Dean of the College of Engineering at Tufts University. In his presentation he cited efforts that colleges of engineering have been mounting to try to retain students as engineering majors. He mentioned that traditional engineering programs have emphasized during the first two years of study almost exclusively the mathematical and scientific theories that undergird engineering. Very capable students were lost to other fields of study simply because they saw no reason or context for what they were studying relative to the field that they thought they were interested in pursuing for their career. They switched majors. In land grant universities, where I have spent the majority of my career, I can attest that technology education is one of the most likely alternative choices for a frustrated engineering major. Times are changing, though. Colleges of engineering are looking at how they can retain these students by providing interesting and challenging technological problem solving opportunities to them from the outset. Moreover, engineers are making connections to what is happening in K-12 education, often connecting with technology education in the process. Dr. Mialoulis mentioned that the engineering-technology education connection is ideal for two reasons. First, we have a wonderful record of doing effective hands-on activities with students. Second, we are worried—worried about how we can maintain our viability and expand our role in the overall educational enterprise.

So how do we make decisions about the proper proportion of time we spend on developing requisite procedural and theoretical knowledge on the one hand, and engagement in actually solving the problem on the other? As educators in this field we are constantly making these decisions, but upon what basis? Students need to have some background related to the problems we are asking them to solve. Otherwise they are dumbfounded and do not know where to start, wasting time in the process. But how far do we go before we let them be creative and when are they sufficiently prepared to engage in the thinking that is required to develop effective solutions to technological problems? When are they prepared to acquire the new knowledge they need to solve the problem at hand when they need it and through their own volition? Williams (2000) provides some very helpful suggestions. As is too frequently the conclusion to my editorial pieces, though, there is very little research to inform us and when we try to extend the findings in this regard from science or mathematics, the apple-orange comparison is often valid. Yet, the decisions we make have grave implications for the efficiency of our teaching practice and ultimately what our students are able to learn and our accountability to them.

The ragged edges of metal hidden under the latch assembly of my storm door and the electrolysis of those screws will continue to haunt me as I count sheep going over the fence in order to fall asleep at night. The sheep that occasionally hits the fence rail with his hoof, though, keeps waking me up. That sheep is the one that represents the requisite theory/procedural knowledge dilemma.

JEL

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Articles

Effects of Modular Technology Education on Junior High Students' Achievement Scores

Cory Culbertson, Michael Daugherty, and Chris Merrill

Background

In the quest to improve public schools, an education in basic technological concepts and systems, or "technological literacy," has been viewed as an important part of a school curriculum (Dugger & Yung, 1995, pp. 7-8). Proponents of technology education have claimed that technological knowledge may be critical to the future needs of all students in the United States. However, proponents of technology education have gone beyond technological literacy to cite even greater benefits for students educated in technology. Many technology educators have claimed that instruction in technological concepts is crucial in fully understanding the concepts in other academic subjects, particularly science and mathematics. These educators have argued that technology education allows students to apply the information that is received in other subjects to real-world situations, thereby increasing their comprehension of the subject matter (Dugger & Yung, 1995; LaPorte & Sanders, 1995; Lewis, 1999; Moss 1999). They also claim that technology education helps students to build and reinforce new patterns of knowledge that make better use of the information that is received in the classroom (Loepp, 1999). Repeatedly, experts in the technology education field have argued that technology education has the ability to strengthen students' achievement in other subjects by providing realistic and practical situations in which students can apply science, mathematics, and other skills. Some commercial curriculum vendors have adopted this argument as well, asserting that a given curriculum will help to boost student performance in mathematics, science, reading, or other areas. As high-stakes testing in basic skills continues to be implemented, it can be expected that educators and administrators will look more closely at any curriculum claiming achievement gains in core academic subjects. Technology education, then, may come under increased scrutiny for its purported benefits to core academic subjects.

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Purpose and Research Questions

Despite anecdotal claims of achievement gains, we do not yet know what impact technology education has on student achievement in other academic subjects. Although some technology educators have provided personal accounts of success, there has been limited research on the effects of technology education on achievement in other academic subjects (Lewis, 1999). Most research to date has only focused on the effects of technology on achievement in physical science (e.g., Dugger & Johnson, 1992; Scarborough & White, 1994), perhaps because the conceptual relationships between technology and physical science tend to be closer than those to other subjects. While this research is certainly warranted, there are other core academic subjects that also may be affected by technology education. Reading and mathematics in particular are two core subjects that receive very little attention in the research surrounding technology education. The range of interaction between technology and other subjects has yet to be fully explored, and the effects of technology education on achievement in other subjects have not been thoroughly investigated (Zuga 1995).

The purpose of this study was to examine whether technology education improves students' achievement scores in the five areas of reading, language arts, mathematics, science, and social studies. Analysis of pre- and post-test scores allowed the analysis and discussion of the following research questions:

1. Do seventh grade students who have participated in one trimester of modular technology education show greater improvement on a test of achievement compared to similar students who did not participate in technology education?
2. Do eighth grade students who have participated in one trimester of modular technology education show greater improvement on a test of achievement compared to similar students who did not participate in technology education?

Related Literature

Technology education may continue as a separate subject or one that is integrated with other school subjects. Either way, the content covered by technology education necessarily overlaps that of other disciplines. Dugger (1993) examined the various fields to which technology is related – science, mathematics, and engineering – and found that technology had strong parallels with all of these fields. Some educators look beyond the interactions with mathematics, science, and engineering and expect technology to come into its own as a full academic subject with established parallels to other academic subjects (International Technology Education Association, 2000). It might be expected that a large body of research would define these links, and that some of this research would focus on the observed interaction of these subjects at the elementary and secondary levels. However, research on connections between technology and other academic subjects is sparse. Liedtke (1999) and Zuga (1995) both commented on a lack of published research on the integration of technology with other subjects. Zuga (1995, 1999) further noted a lack of research on the effectiveness of technology education in terms of contributing to a general education.

Several authors have identified the connection between technology and other academic subjects as a necessary area of inquiry. Lewis (1999) wrote:

> If schooling is to have desired meaning for children, then the various elements of the curriculum must cohere. Lessons learned in one subject must be amplified in others. To take its place squarely in school curricula, technology education must establish itself not just in its own right, but crucially in relation to other subjects. Thus, the relationship of technology to other subjects in the curriculum is a fruitful area of inquiry. (p. 49)

Moss (1999) concurred, noting that "[Technology] supplies the functional context for demonstrating the applications and enriching the meaning of many abstract concepts taught in mathematics and the physical sciences" (p.23).

The Effects of Technology Education on Achievement Gain in Science

Experimental research concerning the interaction of technology and other subjects can be broadly divided into two types: examination of the effects of technology education on other academic subjects, and examination of the effects of other academic subjects on technology education. The effects of interaction can be measured in multiple ways, including affects on achievement, motivation, or other factors. Unfortunately, most of these interactions have not been studied in published literature. The existing literature has almost exclusively focused on the effects of technology education on achievement in other subjects, particularly physical science.

Much of the existing research on the interaction between technology and physical science concerned an integrated physics-technology program called "Principles of Technology." The purpose of these studies was usually to determine whether the Principles of Technology curriculum was equivalent to a conventional physics course. The results of these studies were mixed. Dugger and Johnson (1992) and Hall (1989) found significant achievement gains in physics for students who participated in technology courses. Lewis (1990) and Nicholson (1991) did not.

Dugger and Johnson's 1992 study examined achievement gain for students enrolled in the Principles of Technology course in 15 Iowa high schools. Students were in three groups, those in a Principles of Technology course, a conventional physics course, and no physical science course. Each group was tested for pretest to posttest gain on a test of concepts specific to the Principles of Technology curriculum. The Dugger and Johnson study found significant achievement gain in the groups enrolled in both Principles of Technology and in conventional physics. However, the instrument used to measure achievement gain was written to test the specific curriculum of the Principles of Technology course. In essence, the test was a measure of the skills taught in the class and it is not surprising that the group enrolled in Principles of Technology performed considerably higher than the other group. Dugger and Johnson suggested further research comparing students on a standard test of physics achievement.

Two notable studies in fact used standardized physics tests and found different results. Lewis (1990) also compared gains in physics achievement for students enrolled in either a Principles of Technology curriculum (n=226) or a standard physics curriculum (n=251). Lewis's instrument was based on 30 test questions drawn from a test of physics achievement developed by the American Association of Physics Teachers and reflected content coverage found in both Principles of Technology and physics courses. Lewis found that the Principles of Technology course was comparable to conventional physics courses, in the positive sense, because the achievement of both groups was similar.

Nicholson (1991) similarly measured achievement on a standardized physics test for students enrolled in a Principles of Technology course (n=178). Nicholson measured only posttest achievement and did not employ a control group of physics students. Like Lewis, Nicholson used a standardized assessment test published by the American Association of Physics Teachers. Unlike Lewis, Nicholson found that the Principles of Technology student achievement was not comparable to physics student achievement and further concluded that the instrument selected was not valid for assessment of students enrolled in the Principles of Technology curriculum.

In a study with a slightly different focus, Brusic (1991) examined gains in science achievement for fifth-grade students when technology activities were integrated with traditional science instruction. Brusic conducted a quasi-experimental study of fifth graders in which the treatment and control groups participated in a unit of science. She found no statistical difference in achievement gain between the two groups, but found that the treatment group exhibited greater curiosity regarding the content than the control group did. Brusic noted that incorporation of technology activities might bring potential benefits in increasing students' level of engagement without sacrificing achievement gains.

The mixed results of these studies are not surprising, considering the wide scope of technology curriculum being studied and the varied instruments being employed. Validity of the instrument appears to be a large factor in the results obtained by these studies. Dugger and Johnson, for example, used an instrument that was specifically aligned with the curriculum being studied. Their study reported significant results, where other studies with more generic assessment instruments did not.

The Effects of Technology Education on Achievement Gain in Mathematics and Language Arts

Rogers (1990) conducted a study that examined the relationship between participation in industrial arts education and performance in mathematics courses. Rogers recorded students' participation in specific areas of industrial arts coursework such as drafting and construction, and determined mathematics performance by course grades as reported in the National Longitudinal Survey – Youth Cohort. Rogers concluded that industrial arts education did not significantly enhance students' grades in mathematics, also noting that the contribution of the correlation to the overall mathematics grade was very small – less than one percent. Rogers' study focused on traditional industrial arts. Current developments in the area of technology education suggest the need for a study focused on updated technology curriculum.

Ilott and Ilott (1988) studied the interaction of technology and language arts among a small group ($n = 7$) of elementary students participating in a summer technology enrichment program. The study examined language use in the transmission of verbal instructions among students participating in the enrichment program. The study was qualitative in design and did not measure changes in language usage or skill achievement as a result of experience with technology education.

Conclusions from the Review of Literature

It appears that most research efforts on the interaction of technology and other subjects have focused on the evaluation of specific curricula. Some of these studies have shown parity with existing curricula, and researchers have concluded that the new curriculum does as good of a job as the old one. Most of these studies have focused on physical science.

There are few published studies that specifically examine the potential of technology courses to enhance learning in other academic areas. Rogers found that technology enrollment correlated to lower math grades, but his study did not investigate causes that may lie beneath this correlation. Brusic found that technology activities in a fifth-grade classroom led to increased curiosity, but not to higher achievement. No research exploring the claim that modular technology education improves student achievement in other disciplines could be located. This current study attempted to contribute to the body of research by examining the effects of modular technology education on achievement gain in five different academic areas.

Methodology

The intent of this research study was to determine whether students who have participated in modular technology education show greater achievement gain in reading, language arts, mathematics, science, and social studies than students who have not participated in technology education. This study examined seventh and eighth grade students at one junior high school. A causal-comparative analysis was the most applicable to the research questions and was also useful in minimizing disruption to the normal activities of the selected school and students. Participating students were given a pre-test to measure achievement in each of the following five subject areas: reading, language arts, mathematics, science, and social studies. After the pre-test, each student was randomly assigned to one of three groups: those exposed to a full unit of technology education, a partial unit of technology education, or no unit of technology education. During the time that the groups were not participating in technology education, they participated in a physical education course. After these experiences, all groups again were tested on a post-test of achievement in the same five subject areas.

Instrumentation

The pretest and posttest were the TerraNova Performance Assessment published by CTB/McGraw-Hill. The TerraNova had the advantage of longstanding and thorough data on validity and reliability. The TerraNova has general content validity on par with the best achievement test batteries. The test was developed through numerous revisions with a specific focus on relevance to actual curricular practice (Monsaas, 2001; Nitko 2001). As Nitko noted:

> The developers [of the TerraNova test] began with a thorough analysis of curriculum guides from around the country, of statements of national and state goals and standards, and of textbook series. Efforts were made to align the test content with the NAEP (National Assessment of Educational Progress) and NCTM (National Council of Teachers of Mathematics) frameworks. Teachers, curriculum experts, and other educators reviewed the test specifications and test materials for appropriateness, fairness, and accuracy.

Reliability of the TerraNova test is also high. The individual subtests, as well as composite scores, have reliability coefficients “consistently in the .80s and .90s.” (Monsaas, 2001).

Collection and Analysis of Data

Data for this study consisted of one independent variable – group membership – and ten dependent variables, which are the pre- and posttest scores in reading, language arts, mathematics, science, and social studies. Pre- and post-test scores in reading, language arts, mathematics, science, and social studies achievement were taken directly from the scaled scores reported on the TerraNova test. Scaling of scores is a technique that maps raw scores (number of items correct) onto a predefined scale with equal intervals. Scaled scores can be added or subtracted to calculate meaningful gains.

Statistical analysis of the data consisted of descriptive statistics and an analysis of covariance (ANCOVA) for each academic subject (reading, language arts, mathematics, science, and social studies). Posttest scores were used as the dependent variable, with pretest scores as the covariate and group membership as a fixed factor.

Population and Sample

The population for this study consisted of seventh and eighth grade students at a public junior high school in the Midwestern portion of the United States. The population was 201 seventh grade and 188 eighth grade students. This particular junior high school was selected because it had a modular technology education program that was well suited to the purposes of this study and because of the willingness of the faculty to participate in this study. The study was limited to seventh and eighth grade students to provide uniformity in age and school experience. Two treatment groups and one comparison group were formed from this population. All seventh and eighth grade students in the school were randomly placed in one of the three groups. All three groups took a pretest in September 2000 before the treatment began. The post-test was scheduled in the middle of the school year, in January 2002, so that each of the three groups experienced a full unit, a half unit, or no participation in a unit of technology education.

Treatment and Monitoring

The technology course used for the treatment in this study was a “modular” technology education laboratory consisting of twelve separate learning stations or “modules.” Pairs of students were assigned to each module, spending approximately twelve days at one module and then rotating to another. During each class period, students were expected to follow written instructions and complete computer-based and hands-on activities. The classroom teacher conducted assessment using a mix of electronic, paper, and physical products.

Students rotated among the modules during the twelve-week trimester. Twelve weeks of instruction is 60 days, meaning that students could potentially complete five modules. Because of scheduling, special events, and class management activities, students completed four modules during the twelve-week trimester.

The modules used in the course were commercial packages supplied by a major commercial vendor. The vendor had data available that identified core skills in technology addressed by each of the modules. Table 1 shows some of the core skills published by the manufacturer. The manufacturer did not identify how the core skills were identified, or whether the core skills were taken from a reference source.

Table 1
Selected Core Skills Addressed in the Technology Modules

Reading	Identify, understand and interpret written information
Writing	Communicate information and ideas in writing
Arithmetic	Perform basic computations
Mathematics	Use proper technique to solve or analyze problems
Reasoning	Discover and apply the rules behind relationships

The vendor provided data to correlate each core skill to the specific modules in which it was addressed. According to the vendor, all modules addressed the core skills in writing and reasoning, most modules addressed mathematics and three modules claimed to address core skills in reading.

Analysis of the Data

The analysis of data compared gain scores in the five subject areas and in the three treatment groups using an analysis of covariance (ANCOVA). The ANCOVA allowed the researchers to adjust for initial differences among groups and enabled the researchers to more precisely determine whether outcomes are due to the treatment effect or due to initial difference. Specifically, the pre-test scores were used as the covariate, and the post-test scores as the dependent variable. Group membership was then taken as the fixed factor to determine treatment differences. Since research in this area is still in the exploratory stages, the alpha criterion for significance was set at $\alpha = 0.10$, corresponding to a 90% confidence level.

Results

The study used pre-test and post-test data from 308 students. At the time of the study, the school had a total 7th and 8th grade enrollment of 389 students. Data were not available for the pre-test, posttest, or both for the remaining 81 students. Scores were sorted by treatment group, and mean pre-test and post-test scores for each group were calculated using the Statistical Package for the Social Sciences (SPSS). Rather than give the groups arbitrary names or numbers, the groups are described by "weeks of treatment." Twelve weeks corresponds to the group that experienced the full treatment period of one trimester. Six weeks corresponds to the group that experienced one-half treatment period. The control group is described as "0 weeks" of treatment. Pre-test and post-test means and standard deviations for each group are given in Table 2 for seventh grade students and Table 3 for eighth grade students.

Table 2

Pre-test and Post-test Scores for Seventh Grade Students

	Reading		**Language Arts**		**Mathematics**		**Science**		**Social Studies**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
0 weeks (n=49)										
Pre-test	646	33	642	39	649	33	648	46	647	40
Post-test	670	28	670	43	677	34	676	29	671	29
6 weeks (n=53)										
Pre-test	653	45	643	46	648	33	651	42	652	32
Post-test	667	37	660	42	677	29	677	34	667	31
12 weeks (n=57)										
Pre-test	651	48	655	43	657	33	655	38	660	41
Post-test	675	39	670	45	685	32	681	31	675	33

Pre-test and post-test scores were close to the normed means of the TerraNova, meaning that all groups performed at approximate grade level. In addition, the groups had generally similar pre-test and post-test means. The groups participating in a full unit of technology ("12 weeks" in the tables) have consistently higher pre-test scores than the other two groups. This is true for seven of the ten subject area scores, with seventh grade reading and eighth grade mathematics and science being the only exceptions. The difference was not echoed in the post-test means, which showed no visible trend among groups.

These pre-existing differences on the pre-test were taken into account in the ANCOVA analysis, which adjusted post-test means using the pre-test scores as covariates.

Table 3
Pre-test and Post-test Scores for Eighth Grade Students

	Reading		**Language Arts**		**Mathematics**		**Science**		**Social Studies**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
0 weeks (*n*=54)										
Pre-test	667	35	655	47	669	28	674	33	673	32
Post-test	683	41	677	30	694	33	699	35	684	44
6 weeks (*n*=54)										
Pre-test	669	39	666	46	677	31	678	30	678	31
Post-test	690	32	687	31	701	35	700	34	690	31
12 weeks (*n*=41)										
Pre-test	673	29	667	44	675	30	671	43	680	24
Post-test	688	33	689	36	697	36	696	34	693	37

Table 4
Mean Gain from Pre-test to Post-test

	Reading		**Language Arts**		**Mathematics**		**Science**		**Social Studies**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
7th Grade										
0 wks. (*n*=49)	24	30	28	45	28	26	28	35	24	35
6 wks. (*n*=53)	14	24	17	37	29	23	26	32	15	22
12 wks. (*n*=57)	24	33	15	38	28	23	26	31	15	28
8th Grade										
0 wks. (*n*=54)	16	29	22	40	25	23	25	22	11	30
6 wks. (*n*=54)	21	26	21	30	24	18	22	19	12	26
12 wks. (*n*=41)	15	19	22	35	22	26	25	35	13	26

Gain scores for each subject in the treatment and control groups were calculated for each grade. Mean gain scores are shown in Table 4. As expected, mean gain scores for each subtest were all positive, indicating an increase in achievement from pretest to posttest. The mean gain varied from a low of 11 points in social studies for the eighth-grade 0-week (control) group to a high of 29 in mathematics for the seventh grade 6-week (half unit of technology) group. The gains are at the level that can be expected from a pre-test and post-test separated by one school year.

A visual examination of the gains by group showed differences between groups, but no clear trend could suggest significant differences among the groups. When mean gains were widely separated, it was the 0-week (control) group or the 6-week (half unit of technology) group reporting the higher gain. These gains were not consistent among the subscores, nor were they consistent between seventh and eighth grade. This lack of visual trend was an indication that the gains for the treatment group were not substantially different than those for the control group. However, these gain scores were used for visual analysis only. The statistical analysis relied on ANCOVA methods, which used pretest and posttest scores directly to determine differences between groups.

ANCOVA results are reported in Table 5 for seventh grade students and Table 6 for eighth grade students. The Between Groups *F* value for each subject area indicates the difference in corrected means between the three groups. This value was used to determine the statistical significance of the difference among the treatment and control groups. The *F* values ranged from a low of .085 for eighth grade mathematics [*F* (2, 130) = .085, p = .919] to a high of 2.01 for seventh grade reading [*F* (2, 155) = 2.01, p = .137]. *F* values at this level suggest essentially random differences among group means, a finding that is supported by visual inspection of the mean gain scores in Table 4. In terms of the parameters of this study, ANCOVA results indicate no significant difference among groups at the alpha level of .10, in any subject area in either grade.

Table 5
Analysis of Covariance for Seventh Grade Achievement Scores

Source	***df***	***F***	***p***
Reading			
Pre-test (covariate)	1	172*	< .001
Weeks of Treatment	2	2.01	.137
Within-Group Error	155	(586)	
Language Arts			
Pre-test (covariate)	1	90*	< .001
Between Groups	2	1.22	.298
Within-Group Error	155	(1197)	
Mathematics			
Pre-test (covariate)	1	188*	< .001
Between Groups	2	.266	.767
Within-Group Error	155	(458)	
Science			
Pre-test (covariate)	1	118*	< .001
Between Groups	2	.233	.792
Within-Group Error	155	(577)	
Social Studies			
Pre-test (covariate)	1	135*	< .001
Between Groups	2	1.01	.366
Within-Group Error	155	(522)	

Note. Values in parenthesis represent mean square errors.
**p* < .001

In contrast to the between groups comparisons, the *p* values for the pretest as the covariate were at the $p < .001$ level for all tests, indicating a significant correlation between the pre-test and post-test. This is a favorable result, but not unexpected. The pre-test and post-test were sequential versions of the TerraNova test. The TerraNova has excellent reliability (Monsaas, 2001), and pretest to posttest correlation is therefore quite high.

Table 6
Analysis of Covariance for Eighth Grade Achievement Scores and Weeks of Treatment

Source	***df***	***F***	***p***
Reading			
Pre-test (covariate)	1	106*	<.001
Between Groups	2	.586	.558
Within-Group Error	130	(626)	
Language Arts			
Pre-test (covariate)	1	51*	<.001
Between Groups	2	1.11	.334
Within-Group Error	130	(659)	
Mathematics			
Pre-test (covariate)	1	183*	<.001
Between Groups	2	.085	.919
Within-Group Error	130	(377)	
Science			
Pre-test (covariate)	1	106*	<.001
Between Groups	2	.482	.619
Within-Group Error	130	(514)	
Social Studies			
Pre-test (covariate)	1	92*	<.001
Between Groups	2	.382	.683
Within-Group Error	130	(745)	

Note. Values enclosed in parenthesis represent mean square errors.
*$p < .001$.

Discussion

ANCOVA data indicated that none of the ten potential differences between groups is statistically significant at an alpha level of .10. Although it is impossible to achieve the precision of an ANCOVA by visual comparison alone, a visual analysis of the gain scores for each of the three groups also fails to show any clear trends or any real trend at all. The data gathered do not show statistical or practical differences among the treatment and control groups. The results of analysis indicated that no significant difference existed between the achievement gains shown by each of the three groups in any of the five subject areas. In addition, no visual trends could be discerned among the three groups, as pre-test to post-test gains fluctuated randomly among the groups.

The pretest had a significance of $p < .001$ when used as the covariate in the analysis of covariance, indicating a high pre-test to post-test reliability. Effect sizes were generally low due to the relatively large sample size of approximately 50 students per group. However, the statistical precision offered by these favorable circumstances failed to expose any realistic achievement differences between those students who had participated in the technology course and those who had not.

Conclusions and Recommendations

Based on analysis of the data collected in this study, it can be concluded that there is no significant difference in reading, language arts, mathematics, science, and/or social studies achievement gain between those students who have participated in a unit of modular technology education and those students who have not. The results of this study did not support the claim that participation in a modular technology course can increase students' achievement in other academic subjects. Although it is not the intent of this study to make implications for the entire profession, the finding of no significant difference, combined with similar findings in the literature, leads to the logical conclusion that the body of research knowledge cannot currently support claims of increased achievement in other academic subjects due to participation in modular technology education.

The conclusion of no significant difference in achievement gain between the groups of this study should encourage others to conduct additional research beyond the limits of this study. Certainly, longer exposure to a technology education curriculum may produce measurable differences where this study did not. More importantly, it may be very productive to explore the effect of technology education on higher-order thinking skills, which may not have been measured with the general achievement test used in this study. In particular, a test employing constructed-response items may provide greater discernment of students' higher order thinking skills and may yield different results than those found in this study.

Additionally, the scope of this research should be extended to all types of technology courses. This study examined a modular technology course with content provided by one commercial vendor. One could reasonably expect differing results when testing technology education's impact on achievement when other content delivery methods (standards-based, traditional, or courses delivered with other commercial products) were utilized. Further research could identify types of technology education that are more effective at raising achievement in certain areas. For example, modular technology education courses may have vastly different effects than exploratory or design-based courses on achievement in mathematics and science.

Proponents of modular technology education should exercise caution when making claims of achievement gains in other subjects as a result of such courses. The researchers do not presume to deny such claims on the basis of this limited study. The researchers also recognize that many students in modular technology courses have unique experiences that may show such effects. However, proponents of technology education may have difficulty in finding published research findings that support claims of achievement gains in other subjects. The researchers encourage persons who are evaluating modular technology courses to seek objective evidence to support any perceived benefits of the courses.

Finally, technology educators should strive to develop a rationale for their courses that does not depend on benefits to other subjects. It is unlikely that any course or field of study will ever thrive on the basis of its potential benefit to other fields of study. For example, it is unlikely that professionals in mathematics would attempt to garner support for the field of mathematics with claims that, by taking courses in mathematics, students improve their performance in history classes. Technology education offers unique content and skills that cannot be duplicated in other fields of study. While continuing to pursue the benefits of interdisciplinary studies, technology educators should develop a strong rationale for the program that rests upon the powerful and unique contributions of technology education and not on the potential impact it might have on other disciplines.

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

Theodore Lewis

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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Technology Education Standards Implementation in Florida

Thomas Loveland

Introduction

The release in 1983 of *A Nation at Risk* initiated far-reaching educational reforms through state and federal legislation. A major thrust of school reform has been the use of mandated or recommended educational standards. Standards-based reform is on the agenda in nearly every state in the nation and in almost every content discipline. New federal and state legislation aimed at educational reform and accountability is increasing the pressure for standards-based reform. National educational associations have proposed content standards for their curriculum areas. The National Science Education Standards (NSES) and National Council of Teachers of Mathematics (NCTM) Math Standards are two recognized content standards-based reforms. In 2000, the International Technology Education Association (ITEA) published the Standards for Technological Literacy.

Similar in scope and intent to the National Science Education Standards, the Standards for Technological Literacy were conceptualized as a way to bring more consistency and accountability to the varied technology education K-12 content in the United States (International Technology Education Association, 2000). The organization's goal was to continue the reform of technology education from its industrial arts past to an interdisciplinary and academic future, thus ensuring continued support from educational and political leaders.

The future of technology education is uncertain. Technology is changing so rapidly that it is difficult for schools to keep up-to-date technologies in the classrooms (Dugger & Naik, 2001). States are using strong local programs to build a case for technology education as a basic core requirement for graduation (Newberry, 2001). These challenges persuaded leaders of the Technology for All Americans Project and the International Technology Education Association to follow the direction of leaders in science and mathematics in developing standards for the field of technology education.

The central problem this paper examines is how content standards devised at the national level filter down into classrooms where teachers make the decision to implement or not. A critical element in dissemination of "top-down"

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standards is the role of district content area supervisors. There is a paucity of research that explores district-level factors that contribute to or hinder facilitation of education reform. Educational leaders have a lack of understanding about how attributes of the supervisors and districts themselves affect implementation of content standards in classrooms. Two potential results from the study are more efficient ways of disseminating educational innovations in the future and identification of districts that will require more concerted training in the standards.

The purpose of this study is to examine the relationships between school district and technology education district-level supervisor variables and the technology education teachers' perceived levels of classroom implementation of the Standards for Technological Literacy in their respective districts.

Research Questions

Q1. What is the relationship between perceived teacher implementation of the Standards for Technological Literacy and district enrollment?
Q2. What is the relationship between perceived teacher implementation of the Standards for Technological Literacy and district school density?
Q3. What is the relationship between perceived teacher implementation of the Standards for Technological Literacy and district socio-economic status?
Q4. What is the relationship between perceived teacher implementation of the Standards for Technological Literacy and district technology education supervisor length of service?
Q5. What is the relationship between perceived teacher implementation of the Standards for Technological Literacy and level of district technology education supervisor involvement in the International Technology Education Association?

Implementation Models

What is the effect of national standards on the nation's schools? According to the National Research Council (2002), there are three interacting channels that could be influenced by the adoption of standards: curriculum, teacher development, and assessment and accountability. Curriculum may be affected in the areas of legislative mandates, district curriculum planning, and textbook publishing. Teacher development may be affected by standards in district professional development, colleges of education, and state agencies. Teacher development often focuses on the initial preparation of teachers, certification and licensure, and ongoing professional training.

Assessment and accountability propels change in school systems. They inform the public about how their schools are doing. Assessment informs supervisors about teacher certification, allocation of resources, and sanctions. The introduction of content standards requirements in state curriculum frameworks, school improvement plans, and school accreditation could give districts a strong incentive to adopt standards into school curriculum.

Assessment has a major consequence on college entrance and placement for district students.

How do new national standards get incorporated into classroom curriculum? The National Research Council (2002) identified four critical areas of research regarding the introduction of national standards: contextual forces, educational channels of influence, teachers and teaching practice, and student learning. *A framework for investigating the influence of nationally developed standards for mathematics, science and technology education* (p. 80) describes how innovations move through the educational system.

Theories on diffusion of innovations and information utilization describe constructs and models for the implementation of new ideas. Traditionally, implementation models were based on those from agriculture, business, and medicine. Social scientists and educators initially adopted these market-based models of innovation in the 1940s to explain how to bring about change in school systems. Early models of educational innovations were based on the concept of student test scores and achievement as the only measure of implementation (Havelock, 1976; Rogers, 1995).

In the 1970s researchers began to focus on a different view of educational reform. In a seminal study on educational change, the Rand Corporation (Berman & Pauly, 1975) designed a study through the National Opinion Research Center that carefully studied 293 federally-funded projects in 18 states to determine factors that affected the success of educational innovations. The study concluded that because of the length of time needed for the development of innovations, the incremental rate of educational change and implementation mutation, measuring student outcomes was both premature and inappropriate. Larsen (1985) stated that when utilization of information was described as a single action-based activity that happened in a predetermined period of time, measuring only the narrow dimension of use, research results suggested that utilization did not occur. When implementation included political, socioeconomic, and attitudinal factors, and non-utilization was considered as a category, significant results in utilization studies became more common.

The Rand Change Agent Study hypothesized that superintendents and district officials play major roles in the initiation and continuation stages of innovation. Crandall (1989) described the important contributions that district office-based facilitators make. Their assistance included understanding the needs of students in the district, selecting appropriate innovations to meet those needs, arranging funding, preparing professional development for teachers, and securing support from the school board, superintendent, principals, and teachers. Fullan (1991) stated that district administrators are the key factor in initiating and continuing educational innovations. This leader has a "conceptual understanding of the dynamics of the organization, the processes of change, and the people in (their) jurisdiction (that) represents the most generative…source of ideas about what goes into a plan and what steps have to be taken when things go wrong" (p. 198).

In the Rand Study, multiple regression measures were used to test the variables that affect federal change agent innovations. The researchers summarized seven significant variables that affect the stages of educational innovation. The size of a school district as measured by enrollment (logarithmically adjusted) had the greatest effect. A second variable was enrollment density within the district as measured by the average number of students per school. Whether there were cutbacks in programs in the district in the previous two years had an effect. The fourth variable was the revenue source for the district measured as the percentage of revenue from the state divided by the state average. The fifth and sixth variables measured socio-economic factors: the percentage of families with incomes above $25,000 in 1975 and the percentage of families that were poor and minority. The last significant Rand variable was the length of service of the supervisor in the district. An additional variable according to innovation researchers (Betances, 1999; National Research Council, 2002; Odden, 1991) was active participation in professional networks like NCTM, National Science Association and the ITEA.

Measurement of the level of implementation as a dependent variable has centered on seven or eight stage models (Cousins & Leithwood 1993; Larsen 1985). These models are based on ascending levels of implementation of information and educational innovations. A level one response indicates a lack of awareness of the innovation. Level eight indicates full adoption of the innovation with adaptation to local conditions. Participants choose the self-perceived level that most closely identifies their current level of implementation of the innovation.

A post-study inquiry about the model questioned how to measure the response from someone who completely understands the innovation but disagrees with it or refuses to implement it. Those individuals may have chosen level three or discarded the survey instrument. Additional information in level three might have helped clarify this point. The operational model for the Florida study reported herein and titled *Levels of Implementation of the Standards for Technological Literacy* was adapted from the Cousins and Leithwood 1993 model by substituting the words *Standards for Technological Literacy* for the original word *intervention*. The model is presented in Table 1.

Methodology

A study was designed to look at district-level predictors in the implementation of new content standards, specifically the Standards for Technological Literacy in Florida. The study used a correlation research design to look at the relations between district size, enrollment density, district socio-economic status, district supervisor length of service, and participation in professional networks and technology education teachers' self-reported perception of implementation of the Standards for Technological Literacy within their classrooms. Table 2 summarizes the complete set of variables.

Table 1
Levels of Implementation of the Standards for Technological Literacy

1	I am not aware of the Standards for Technological Literacy.
2	I am aware of the Standards for Technological Literacy but have not seen a copy (e.g. did not read it or attend workshop).
3	I was exposed to the Standards for Technological Literacy (e.g., read report, attended workshop) but subsequently, have done nothing about it (e.g., no action, no discussion with colleagues/peers).
4	I am currently considering information from the Standards for Technological Literacy (e.g., being discussed or reviewed with colleagues/peers).
5	Based on information from the Standards for Technological Literacy, I have taken steps toward action (e.g., decision to use, plans being made).
6	I am making partial use of information from the Standards for Technological Literacy. Actions have been taken on selected features of the standards, but others have been disregarded.
7	I am making full use of the information from the Standards for Technological Literacy in the form in which it was presented.
8	I am making full use of the information from the Standards for Technological Literacy in a form modified to fit my needs.

In order to establish content validity of the instruments and scales, a focus group of professional educators was utilized. Twelve educators attended a Standards Interpretation Workshop in July 2002 in Atlanta, Georgia. Sponsored by the International Technology Education Association, it attracted participants from four southeastern states. The participants included three state supervisors of technology education, two technology education university professors, one district technology education supervisor, one school principal (recent technology education middle school teacher) and five high school technology education teachers. This convenience sample allowed for a wide range of perspectives on technology education. During the workshop, time was set aside for the participants to review the proposed instruments and scales for this study. In pairs, the educators were asked to review a supervisor and teacher survey for clarity of the questions and instructions. They were also asked to review three hierarchical scales: teacher certification, involvement in ITEA, and classroom implementation of the standards. A careful analysis of the group responses led to modest changes in the instruments.

After the study was approved by the Office of Research Compliance at the University of South Florida, a pilot study of the teacher measure was undertaken. Eleven copies of the teacher package were mailed out to a random selection of technology education teachers in a medium-size district in west central Florida. Seven of the eleven teachers responded to the survey, a 64% response rate. No follow-up surveys were sent out. The collected surveys showed that the teachers understood the directions and responded in appropriate ways.

Table 2
Variables Investigated

Variable Name	Type	Q	Measure	Scale
District Enrollment	IV	1	Logarithmic transformation of HS and MS enrollment from Florida DOE Website	Continuous
District School Density	IV	2	Calculated from HS and MS enrollment divided by number of HSs and MSs	Continuous
District Socio-Economic Status	IV	3	District free and reduced lunch % as reported on the Florida DOE Website	Continuous
Supervisor Length of Service	IV	4	Supervisor self-reported years of service	Continuous
Supervisor Involvement in National Organization	IV	5	Supervisor self-reported level of involvement with ITEA: (4) levels	Ordered categorical
Teacher Implementation of Standards of Technological Literacy (*STL*) in Classroom	DV	all	Teacher self-reported level of *STL* implementation from eight level scale based on Cousins and Leithwood	Continuous derived from pooled teachers (ordered categorical scale)
Teacher Length of Service	NV	all	Teacher self-reported years of service	Continuous
Teacher Certification Type	NV	all	Teacher self-reported type of certification (5) levels	Continuous derived from pooled teachers (ordered categorical scale)

Notes. In the Type category IV = independent variable, DV = dependent variable, and NV = nuisance variable to be adjusted out. The Q category refers to the research question with which the variable is associated.

The original dependent variable scale (Larsen, 1980) was used with qualitative interviews and the Concerns-Based Adoption Model instrument in a study of 39 mental health facilities reporting levels of information utilization. Cousin and Leithwood (1993) adapted the Larsen scale for their study with 535 Ontario elementary school principals. Their study was conducted utilizing path analysis with LISREL 7. They reported high reliability and validity but did not provide supporting data.

In order to establish concurrent validity of the dependent variable scale, two strategies were developed to compare the self-reported level of implementation by teachers with the reality of their classroom implementation. The first strategy involved the use of a second teacher survey that asked 35 questions to identify the level of implementation. This survey was adapted from a Standards-Based Technology Education Teacher Matrix of Criteria developed and distributed by the International Technology Education Association during their third phase of standards implementation. Twenty technology education teachers from Florida were randomly selected and interviewed using this questionnaire. A rating rubric was developed for the ITEA standards matrix to code teacher responses and assign a true level of implementation. The true level of implementation was compared with the teacher's self-perceived level of implementation. A Pearson correlation coefficient was determined to be .97, a remarkably high correlation for the 20 teachers in the sample. This value indicates that both surveys have good validity.

The second strategy was to use a qualitative method of personal interviews with teachers in their classrooms. Seven technology education classrooms that represented each level of implementation above level one were visited in varying districts and school levels. A list of questions was developed to ask teachers in order to elicit responses that showed their true level of standards implementation in lessons and curriculum. Their responses indicated that they had chosen the level of implementation that matched what they were doing in their classroom.

In July 2002, two Florida Department of Education websites were accessed to provide data for the first three questions: district enrollment, district school density and free and reduced lunch rate. The websites were:

- http://www.firn.edu/doe/eias/flmove/county.htm
- http://info.doe.state.fl.us/fsir/

Responses for research questions four and five were collected from a supervisor survey. The survey asked for the district name, number of years of service as a supervisor, level of involvement with ITEA, and whether their technology education supervisor duties were fulltime or part-time.

The one ordered categorical question asked supervisors about their level of involvement with the ITEA. Their choices were: 1) *None* (no involvement in ITEA, not a member), 2) *Minimal* (member of ITEA, occasionally reads articles in *The Technology Teacher*, ITEA has little effect on my supervisory duties or guidance given to teachers), 3) *Active* (member of ITEA, attends national conferences occasionally, reads articles in *The Technology Teacher* with strong to moderate interest), and 4) *Very Active* (member of ITEA and attends national conferences regularly, attends association-designed training on Standards for Technological Literacy, reads articles in *The Technology Teacher* with strong interest, or writes articles for publication in ITEA journals and websites).

Surveys were distributed at a meeting of the Florida Association of Supervisors of Technology Education. Survey packages were subsequently mailed to the non-attending supervisors. Follow-up emails, letters, and personal phone calls resulted in valid responses from 65 of the 67 (97%) district technology education supervisors in Florida.

A different survey was prepared for distribution to technology education teachers in Florida. In addition to the implementation level, the teacher survey asked for information about two nuisance variables. The teacher survey asked respondents for their district name, years of teaching experience, level of certification, and level of implementation of the Standards for Technological Literacy in their classroom. One ordered categorical question asked teachers about their certification as an industrial arts/technology education teacher. The choices were: *Level 1*: no certification, *Level 2*: out of field certification, *Level 3*: local district certification, *Level 4*: State 6-12 Industrial Arts/Technology Education temporary certification or *Level 5*: State 6-12 Industrial Arts/Technology Education professional certification.

Collection of teacher data was accomplished in several ways. An online survey was posted on the Florida Technology Education Association (FTEA) website. Surveys were distributed at the FTEA conference in 2002. A list of 1600 Florida technology education teachers (sorted by district) was received from the State Supervisor of technology education. This list was compared to the lists provided by district supervisors of their technology education teachers in order to create a valid list of teachers. Through mass mailing of survey packages, postcards, and online data collection, the 1,083 Florida technology education teachers were contacted. Four hundred valid responses from 62 districts were received, a 37% response rate statewide. These teacher responses, matched with their supervisor's responses, yielded 60 of 67 (89.5%) Florida districts with valid responses for each of the variables. The district level means were used in the data analysis for the study. For example, 14 teacher responses from district #16 were pooled to create district #16 data on years of service, certification level and level of implementation of the standards.

Results

The frequency distribution of Florida technology education teachers self-perceived levels of implementation of the standards is presented in Table 3. When measured at the individual teacher level (*n* = 400), this distribution was U-shaped. There were many teachers implementing at very high levels or not at all. When the data was pooled by district (*n* = 60), the distribution was normal. Three years after release of the Standards for Technological Literacy, 42% of participating Florida teachers reported using the standards at the top three levels of use. Sixty-three percent had read the standards.

Descriptive statistics, correlation matrix and multiple regression were utilized to analyze the effects of the independent variables on teacher's perceived level of standards implementation. The descriptive statistics for each variable are in Table 4. The teacher variables are given for both statewide (*n* =

400) and district pooled (*n* = 60). The district pooled data were used for the correlation and multiple regression analysis.

Table 3
Frequency Distribution of Teacher Levels of Implementation

Implementation Level	*f*	%	Cum. *f.*	Cum. %
1. No Awareness	76	19.00	76	19.00
2. Aware, but Not Read	70	17.50	146	36.50
3. Read, but No Action	36	9.00	182	45.50
4. Considering Information	18	4.50	200	50.00
5. Decision to Use	33	8.25	233	58.25
6. Partial Use	65	16.25	298	74.50
7. Full Use As Is	23	5.75	321	80.25
8. Adapted Full Use	79	19.75	400	100.00

Note: *n* = 400

Table 4
Descriptive Summary of Independent, Nuisance and Dependent Variables

Variable	*n*	*M*	*SD*	Skewness	Kurtosis
District Enrollment (log)	60	3.89	0.64	0.102	-0.755
District School Density	60	1052.00	468.00	0.251	-0.575
District Socio-Economic Status	60	44.38	11.98	0.358	-0.267
Supervisor Length of Service	60	9.07	7.88	1.251	1.085
Supervisor Involvement in National Association	60	1.55	0.85	1.369	0.806
Teacher Perceived Level of *STL* Implementation	400	4.36	2.61	0.090	-1.512
Teacher Perceived Level of *STL* Implementation (District Means)	60	3.79	1.80	0.507	0.127
Teacher Length of Service	400	13.34	10.52	0.643	-0.838
Teacher Length of Service (District Means)	60	12.96	7.47	0.663	0.604
Teacher Level of Certification	400	4.29	1.18	-1.256	-0.109
Teacher Level of Certification (District Means)	60	4.00	1.10	-1.188	0.525

Several regression models were formed in order to understand the overall R^2 attributed to the five variables, the unique contribution of each variable, and the contribution of each variable when controlled for two teacher nuisance variables: length of service and type of certification. The first three were selected to give an overall picture of the effect of the independent variables in combination in predicting the implementation of the technology education standards in district classrooms. The last five models were designed to answer specific research questions posed in the study.

After the district and teacher data were compiled and sorted, several data analysis steps allowed the researcher to analyze the assumptions about the multiple regression analysis. The first assumption, independence, was not violated because district means were used and there appeared to be little contact between teachers within and across districts.

The second assumption was that the predictor variables were fixed. The predictor variable, involvement in the national association, was the only variable based on a categorical scale that is fixed. Regression is robust to violations of this assumption.

The third assumption was that the predictor variables were measured without error or bias. This assumption is directly related to the reliability of the predictor variables. In the study, the predictor variables were explicit and unambiguous to answer and so it appears that the third assumption was not violated.

There are three additional regression assumptions analyzed: normal distribution of residuals, common variance or homoscedasticity of errors, and linearity. None was determined to be interfering with the robustness of the multiple regression analyses.

In addition to the assumptions of the regression analyses, there are three statistical issues addressed in the study: multicollinearity, bias in R^2, and influence of outliers. Multicollinearity is the overlap between two predictor variables. This did not appear to be a problem in most of the regression analyses. The correlation matrix (Table 5) revealed only one highly linear relationship among the 28 correlations. The Pearson correlation coefficient between district enrollment density and district enrollment (log transformation) was a strong .84 with a p value $<.0001$.

The second issue of concern, bias in R^2, could be a problem in the study. R^2 bias is a function of the number of predictor variables and sample size. R^2 bias was minimized through the use of the adjusted R^2 in all regression models. Six indicators of influential observations were examined to evaluate the third issue of concern. All six pointed to particular observations, but the removal of those observations did not change the number of significant variables in the study.

Table 5
Correlation Matrix of Independent, Nuisance, and Dependent Variables Measured at the District Level

	Implementation	Enrollment, Log Adj.	District School Density	Social Economic Status	Supervisor Experience	Supervisor ITEA Invlovement	Teach. Yrs. Experience
Enrollment, Log. Adjusted	.37*						
District School Density	.45*	.84*					
Social Economic Status	.01	-.09	-.15				
Supervisor Yrs. Experience	.07	.08	.14	-.12			
Supervisor ITEA Involve.	.18	.65*	.56*	-.07	.09		
Teacher Years Experience	-.22	-.02	.00	-.06	-.10	.05	
Teacher Certification Level	.09	.39*	.40*	-.07	.10	.20	.40

Notes: $n = 60$. * $p < .05$.

Findings and Implications

The key findings of the study were that higher district enrollment and school enrollment density were linked to higher levels of perceived implementation of technology education standards in Florida schools. Sixteen percent of the adjusted variance was attributed to district school density. The increase in implementation may be related to increased opportunities for teachers to work with colleagues. Schools with many technology education teachers increase the likelihood that some of the teachers have been exposed to the standards.

Eight percent of the adjusted variance was attributed to district enrollment. Larger school districts have larger budgets, greater flexibility to direct funds, more inservice training, and more political flexibility. District socio-economic status and supervisor length of service had no apparent effect on the implementation level of the districts. There were mixed results regarding the involvement of the supervisor in national associations due to a highly skewed frequency distribution. Eighty-three percent of the supervisors have minimal or no involvement in the ITEA. These results are summarized in Table 6.

The major implication of the study is that it will be a challenge to implement content standards and other educational innovations in small districts. There may need to be outside institutional and political pressure through funding, staff development, and state mandates in the areas of statewide student assessments, district accountability, and teacher licensure. National educational associations may need to increase their outreach efforts to low enrollment districts through regional teacher training, local consensus building, and membership increases of key constituents.

Table 6
Multiple Regression Summary

Variables	**Pearson *r***	***p***	**Adj. R^2**
School district density	.448	< .000	.161
School district enrollment	.354	.006	.081
Supervisor involvement in national association (ITEA)	.189	.148	.011
Supervisor length of service	.083	.530	-.016
School district socio-economic status (free/reduced lunch)	.006	.961	-.017

Note: *n* = 60.

In order to encourage low enrollment districts to increase their use of the content standards, legislators and educational institutions, through incentives, may consider the incorporation of content standards like the Standards for Technological Literacy into statewide student high-stakes assessments and accountability expectations. State curriculum frameworks could be written to the standards. School improvement, school technology, and school accreditation plans could call for demonstration of standards-based curriculum within schools and districts. Professional development of teacher interns and licensure of beginning and professional teachers could include criteria that require the demonstration of content area knowledge and concomitant standards, and show that they can teach using standards-based instructional methods and curriculum. National certification and merit pay guidelines could require competence in the standards. These efforts and the adoption of content standards in state and national student assessment instruments will likely compel curriculum developers and textbook publishers to include the standards in their educational materials.

It is likely that there are small districts that resist top-down mandates and pressure to increase implementation of the Standards for Technological Literacy. During the qualitative discussions with teachers, several high implementing teachers with low district support emphasized their grass roots efforts in adopting the standards. These teachers acknowledged that they received their support from fellow teachers across the state through web sites, email, and work with associations like the Florida Technology Education Association. Commitment from teacher educators can help overcome district indifference, lack of resources, and poor training.

National associations like the International Technology Education Association can develop local consensus on the value of the standards through media dissemination of information about the standards. Contacts with trade industry associations could assist in building awareness in many communities about the need for technological literacy. Research studies on the effectiveness of standards-based curriculum could be supported by the national associations.

Standards-based curriculum and assessment models could be developed into training materials from studies on best practices. The associations could then work with state technology supervisors to identify low enrollment districts. Regional standards training could assist these low enrollment districts in providing their technology education teachers with opportunities for professional development that would not otherwise be available to them.

National content organizations can increase memberships of key constituents. District supervisors of technology education should become more involved and active in their content organizations. Attendance at regional standards inservices would be a step in that direction. Increases in involved supervisors would allow researchers to accurately assess whether association involvement is a significant factor in implementation of content standards.

Teacher educators may be having an effect on implementation of innovations by teaching new teachers about the new content standards. Teachers, in the early stages of innovations, are the ones who commit to innovations and sustain the innovation when the development money dries up. Odden (1991) discussed how standards implementation is facilitated by teacher participation in professional activities, leading to strong, informally coupled networks of teacher experts. An infusion of dedicated teachers into the national and state content-related associations should increase the level of standards implementation within states and districts.

The author would be remiss in not addressing the viability of using the Rand Study as the conceptual framework for the study. At the time of the Rand Study, the majority of educational innovations being studied were redistributive in nature. Following the Great Society programs of the late 1960s, many federally funded educational programs were designed to right the wrongs of society. Desegregation, compensatory education, and bilingual education had a contentious implementation process. These were issues in which teacher collegiality worked against implementation. Educational innovations in the 1990s tended to be about curriculum development so that teacher collegiality worked in favor of implementation. Unlike the Rand Study projects that were federally funded demonstrations, the Standards for Technological Literacy are being implemented largely through research, publication, and inservice efforts paid for by states and districts.

While the Rand Study focused on all educational programs, the current study focused on an educational innovation for technology education. The historical ties of technology education to vocational education and industrial arts, contrasted with the newly emerging technologies of today, result in many factors that may have affected the results of this study. Developmental work at the Jackson’s Mill Symposium, The Ohio State University, and the Standards for Industrial Arts Program Project all exhibited a continual reevaluation and understanding by leaders in the field prior to the Technology for All Americans Project. Equitable funding through Perkins Grants has helped in the restructuring of classrooms into modern technology education laboratories.

The Rand Study presented five conclusions on how the characteristics of school districts and projects affected project outcomes of the innovations. First, the educational methods used by a project had a limited effect on implementation and continuation. Second, project resources were poor predictors of outcomes. Third, a more ambitious project scope was more likely to stimulate teacher change and involvement. Fourth, active commitment by district and site leaders was essential to project success and continuation. Fifth, implementation strategies developed locally dominated change agent projects. Teacher networks, strong local capacity and will, and enabling teachers to implement change are still critical factors in implementing educational innovations (Crandall, 1989; McLaughlin, 1991). None of these Rand Study conclusions were contradicted by the current study.

Summary

Larsen (1985) stated that public organizations find it difficult to introduce new ideas. The use of innovations may require lengthy negotiation, planning, testing, and the establishment of support and consolidation. The Standards for Technological Literacy and other content standards have followed this prescribed path of implementation.

The reported level of implementation of the technology standards in Florida after only three years is notable. This may be a result of the close consultations that the International Technology Education Association had with the National Council of Teachers of Mathematics and the National Science Association. It may be a reflection of the depth of inservice training provided across Florida by the state supervisor of technology education working with the Florida Technology Education Association. The Standards for Technological Literacy were adapted into the Florida Curriculum Frameworks for technology education in 2002. The state has provided standards-based curriculum materials developed by the Center to Advance the Teaching of Technology and Science (CATTS), a project of the ITEA, to teachers and districts. Finally, Florida teachers are involved in many standards-based pilot programs like the *Tech-know Project*, headquartered at North Carolina State University and directed by Dr. Richard Peterson.

The variability in the levels of implementation across Florida districts is a reminder that more will have to be done to realize the goal of helping students become technologically literate. With a sustained effort, legislative and educational leaders can transform the content standards into an effective instrument for the fundamental change of technology education classrooms and students, as envisioned by the national association.

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The Role of Design Drawing Among Children Engaged in a Parachute Building Activity

Dougal MacDonald and Brenda Gustafson

Introduction

In recent years, many elementary (ages 5-12) science programs in North America have incorporated what is called design technology, design and technology, technology, technological problem-solving, and/or problem-solving through technology (ITEA, 2000; Alberta Education 1996; Kimbell, Stables & Green, 1996; Layton, 1993). Design technology involves designing and making products to meet some need, and is "directly concerned with the individual's capacity to design and make, to solve problems with the use of materials, and to understand the significance of technology" (Eggleston, 1996, p. 23). In elementary classrooms, lessons often focus around designing and building models of structures and mechanisms such as bridges and vehicles.

Design technology involves children in problem-solving processes perceived as central to the development of their capability to do quality work. These processes have been referred to as procedures, procedural skills, facets of performance, facets of capability, problem solving skills, and thinking processes (Bottrill, 1995; Custer, 1995; Johnsey, 1997; Kimbell, Stables, & Green, 1996). Examples include investigating, planning, modeling, making, and evaluating. One activity that plays an important role in many of these problem-solving processes is drawing. Drawing can be a method of recording information, a component of planning, and/or a technique of two-dimensional modeling.

The two main approaches to studying design drawing have been to investigate the practice of design professionals such as architects and engineers, and to explore children's classroom design technology drawing. These approaches raise at least three important issues from which the focus questions for the present study are derived:

- What are the characteristics of children's design technology drawings?
- Could an analytic scheme, derived from professional drawing practice, be used to analyze children's design technology drawing?
- How might teachers intervene in order to enhance and broaden children's authentic use of drawing in design technology?

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Related Research

Classroom Drawing Practice

Recent research on classroom drawing practice in design technology has focused on four main areas:

- The role of drawing in creating and developing ideas
- The link between drawing and making
- The respective roles of 2-dimensional drawing and 3-dimensional modeling
- The effects of the explicit teaching of drawing

Several researchers (Garner, 1992, 1994; Anning, 1997; Hope, 2000; Smith, 2001) state that much classroom design technology drawing overemphasizes the role of drawing in communicating ideas and under-emphasizes its role in creating and developing ideas. Garner notes the undervalued role of drawing in the manipulation and exploration of design. He claims that much professional design drawing is never seen by others and that its main purpose is to assist the designer to create and develop ideas rather than to communicate with others (Garner 1992). He also points out that an advantage of sketching is its ambiguity, making it a useful medium for generating ideas (Garner, 1994).

Anning (1997) notes that “drawing offers a powerful mode for representing and clarifying one’s own thinking” (p. 219). She asserts that young children use drawings to explore and generate ideas, similar to designers. Hope (2000) concludes that the overwhelming focus of research on children’s drawing has been on drawing as representation whereas “the activities most closely associating drawing with designing are those of investigating and generating ideas” (p. 108). Smith (2001) suggests that too much emphasis on representation, i.e., the perfect drawing, could restrict opportunities for discovering new ideas.

Researchers (Rogers, 1998; Hope, 2000; Fleer, 2000) have also investigated the link between children’s design plans and what they make. Rogers studied young children as they designed, made, and appraised vehicles using commercial kits. He found a weak link between the designing stage and the making and appraising stages of their work in that children did not refer back to their design drawings when making. He suggests three possible reasons for this disconnection: lack of a clear idea of what designs should look like, not understanding the purposes for drawing a design, and deficits in drawing skills (Rogers, 1998).

Hope (2000) explored how young children use drawings in planning a product. He concluded that more understanding is needed about how children develop drawing skills. Fleer (2000) found that even some very young children use their drawn plans as a guide to making. She suggests that two possible reasons some children do not use drawn plans are insufficient technical knowledge and insufficient detail in their plans.

Some researchers (Smith, 2001; Welch, 1998) have investigated the respective roles of two-dimensional (drawing) and three-dimensional modeling in classroom design technology. Welch (1998) found that Grade Seven students quickly replaced drawing with three-dimensional modeling, i.e., working with the project materials. He calculated that students spent only about 8.5% of their total design time sketching and drawing (Welch 1998). Similarly, Smith notes that pupils in England appeared reluctant to use 'sketch modeling' (Smith 2001).

An interesting sidelight on the findings regarding 2D and 3D modeling is that many professional designers recognize that the degree of abstraction in a design is controlled by the form of the modeling. Drawings are simpler and more abstract than 3D models, hence they are more ambiguous and allow for more interpretation (Lindsey, 2001).

A number of researchers advocate explicit teaching of drawing skills (Anning, 1997; Rogers, 1998; Fleer, 2000; Smith, 2001). For example, Anning (1997) proposed that teachers could do more to enhance children's graphicacy through explicit teaching of drawing, as well by becoming more aware of how graphicacy can contribute to children's learning. She urges more research into developing graphicacy in educational and non-educational contexts.

Fleer (2000) advocated assisting children in their drawing through teaching interventions such as making them more aware of the specific purposes of drawing and familiarizing them with different perspectives. Smith (2001) advocated further research into sketching as an important aid to designing. He suggested that a better understanding is needed into "how to develop pupils' sketching skills which provide opportunities for ambiguity and hence an opportunity for creating new ideas" (p. 8).

Some investigators have studied the effects of explicit teaching of design drawing. Welch, Barlex, and Lim (2000) investigated whether explicit teaching better enabled Grade Seven students to use two-dimensional modeling to help them design a case for audiotapes, videotapes, or CDs. They concluded that students tended not to use sketching to explore solutions but moved quickly to three-dimensional modeling. The researchers attribute this to limited sketching skills and experience. They speculate that different methods of modeling may be appropriate to different tasks.

Smith, Brochocka, and Baynes (2001) used explicit teaching of 2D and 3D modeling, including sketching, to determine how pupils used them. Pupils were instructed to move between 3D and 2D design media several times while working. The researchers concluded that "the revised approach was effective and this conclusion was confirmed by structured interviews with each of the pupils involved" (p. 125).

Professional Drawing Practice and Classroom Drawing Practice

There is a tradition of educators drawing on professional practice to inform classroom practice. For example, Robert Gagne's list of science processes, including observing, classifying, and predicting, was developed in the 1960s, based on his observations of the methodologies of professional scientists (AAAS, 1967). These processes are still in the repertoires of science educators today. For another example, the writing process approach to written language, widely popularized by educators such as Donald Graves, originated with a 1964 article by Gordon Rohman, which drew upon how professional writers go about their work (Walshe, 1981).

While some researchers suggest that professional and classroom practice can inform each other (Davies, 1996), others caution against the unproblematic use of accounts of professional practice as prescriptions for classroom practice (Medway, 1994). Medway notes that "while the actions performed in both settings, school and work, may be similar at a behavioral level, their meaning will be quite different since the student works within a distinctively educational matrix of purposes, expectations, conditions and criteria (e.g., working for marks, without financial risk, etc.)" (Medway, 1994, p. 88). Medway suggests that one approach is to view what occurs in professional practice as "indicators of curricular possibilities" (p. 104) rather than as prescriptions.

Methodology

This study took place at an elementary school in a middle-class, urban neighborhood. Visits were made to one Grade 6 (ages 11-13) classroom during the teaching of a twelve-week unit that combined a science inquiry unit (*Air and Aerodynamics*) with a design technology unit (*Flight*). The twenty-seven children (14 male; 13 female) had been coded as Academic Challenge (high achieving) students.

The research presented in this paper focuses on two lessons in which the children designed, made, and tested model parachutes. These lessons were selected because in each lesson pupils were directed by their teacher to draw pictures of their parachutes. The parachute activities were scheduled towards the end of the unit and were presented by the teacher as a series of structured action tasks focusing on product construction and testing.

Data Collection

In this study, we assumed that children's thinking was expressed through their drawings as well as through their verbal discourse, writing, and actions. Drawings, audio-tapes, field notes, photographs, and written work provided information about children's efforts to frame, negotiate, and complete tasks.

Children's drawings and written work were photocopied. Audio recordings were made of whole class discussions and one group of four children's conversations. Field notes and photographic evidence were compiled to lend insight into children's actions and interactions within the group.

Data related to the teacher's perceptions of scientific and technological problem solving were also gathered through semi-structured interviews prior to and during the teaching of the unit. Anecdotal records were kept of informal conversations with the teacher that occurred prior to and after each lesson.

Lesson and interview transcripts were provided to the teacher and she was invited to amend or clarify the meaning of any verbal comments.

Data Analysis

The following analytic scheme and clue structure, based on a research methodology developed by Roberts and Russell (1975), was used to analyze children's drawings (Figure 1). The analysis involved comparing children's drawings to the scheme to detect similarities and variations. The analytic scheme and clue structure, therefore, was used as a lens through which to view the children's design drawings and as a way to derive helpful insights about the role of drawing in classroom design technology.

Table 1
Analytic Scheme and Clue Structure.

Category 1 - The drawings include a beginning sketch	
Clue A.	A sketch is made at the beginning of the project
Clue B.	The sketch indicates the pupil's initial thoughts/key ideas about the project.
Clue C.	The sketch is exploratory and conceptual rather than representational.
Clue D.	The sketch is made quickly and spontaneously.
Clue E.	The sketch includes images and words.
Category 2 - The drawings include elaborating and refining drawings	
Clue A.	A series of freehand and hard-line drawings are made during the project.
Clue B.	The drawings are shared with other members of the design team.
Clue C.	The drawings transform the ideas expressed in the initial sketch.
Clue D.	The drawings elaborate, refine, expand, and develop the pupil's initial ideas.
Clue E.	The drawings show increasing accuracy and detail, including dimensionally.
Category 3 - The drawings include a final presentation drawing	
Clue A.	A drawing is made at the end of the project.
Clue B.	The drawing is a recognizable representation of the finished product.
Clue C.	The drawing can be used by those outside the design process as a guide to making.
Clue D.	The drawing is hard-line, finished, precise, and detailed.
Clue E.	The drawing is labeled and measured.

The analytic scheme and clue structure were developed through analyzing research literature on how drawing is used in professional practice (e.g., by people working in engineering, architecture, and industrial design). The theoretical perspective incorporates two main ideas:

1. Professional designers use drawing both to represent and generate ideas (Arnheim, 1969; Bucciarelli, 1994; Ferguson, 1999; Lindsay, 2001; Robbins, 1994).
2. Professionals use three types of drawings in their work: initial sketches, elaborating and refining drawings, and final presentation drawings (Crowe & Laseau, 1984; Do & Gross, 2001; Laseau, 1980; Robbins, 1994; Schenk, 1991).

Four features of drawings identified from descriptions of professional practice are (Cross & Cross, 1998; Ferguson, 1999; Fraser & Henni, 1994; Robbins, 1994; Steele, 1994):

1. Timing or when the drawings were made (‘A’ clues).
2. Intended audience (‘B’ clues).
3. Purpose of the drawings (‘C’ clues).
4. Salient observable characteristics (‘D’ and ‘E’ clues).

It should be noted that during the analysis that a clue may be sound but the observable evidence may be missing from the drawing. In such a case, plausibility will temporarily win over presence. That is, methodologically speaking, it is not a clear-cut test of a clue if the behavior does not occur (MacDonald, 1995). For example, the omission could be a function of the context of the lesson, the teaching strategy, and/or the experience of the teacher.

Following the analysis, a member check was performed for factual and interpretive accuracy and to provide evidence of credibility (Denzin & Lincoln, 2000; Janesick, 2000; Lincoln & Guba, 1985). An experienced science education researcher uninvolved with the generation of the analytic scheme performed the check by reviewing the drawings, data analysis, and study interpretations. The researcher was asked to affirm whether the analytic scheme had overall credibility and whether study interpretations and conclusions were an appropriate reflection of the data (Lincoln & Guba, 1985). This researcher’s suggestions were incorporated into this paper.

Lesson Context

Lesson 1 - Constructing Model Parachutes (45 minutes)

The teacher began the lesson by reviewing activity expectations, constraints, and materials. Each child was instructed to make a model parachute displaying one canopy no larger than 30 cm x 30 cm, or else two or more canopies that together would not exceed this measurement. The teacher supplied materials not brought by the pupils. Parachute design was to be informed by concepts about flight addressed in previous lessons (e.g., properties of air, drag, and gravity) plus any other knowledge children could draw on. Once their parachutes were constructed, children were to draw a picture of their design.

The teacher also announced that the parachutes would be tested in the gymnasium on the second day. The children were urged to think ahead to the testing and consider potential design modifications to see if their parachute needed alterations. The children were encouraged to construct their best parachute design to test competitively against other children's designs.

The children worked in groups to make their parachutes and then draw their final designs. At the end of the class, all children presented completed or nearly completed parachutes. The teacher provided an extra half hour later in the day for completing the individual parachute drawings.

Lesson 2 - Testing Parachutes (105 minutes)

The teacher reviewed behavioral expectations and testing procedures before entering the gymnasium. Each child was directed to test his or her individual parachute by standing on a chair on the gym stage and then releasing the parachute. A parent volunteer would time the descent. The goal was to achieve the slowest possible descent.

After each group member had completed one drop, the group would discuss results and select one group member's parachute to modify for the second and final test. The teacher advised the children to discuss who had the slowest descent time, analyze what was good about the parachute and how it differed from faster parachutes, and then decide what to modify to make it the best. Children were urged to use all the information they had to improve their chosen parachute because they would only get one chance for the second test.

Once children were in the gym, a second Grade 6 teacher, whose class was also designing and testing parachutes, restated the testing rules and identified the testing method, drop height, and canopy size as control variables that would make for a fair test. Behavioral expectations were again reviewed. The children were given about 80 minutes to drop-test their individual parachutes, select one parachute for modification, carry out (or not carry out) modifications, and then re-test their final group design. Once the final test was completed, children were instructed to draw their final group design.

Findings

Sixteen children produced two drawings each of parachutes. The first drawing was made after each member of the group had built an initial parachute. The second drawing was made after the group had selected, modified (or not modified), and tested the individual group member's parachute that the group identified as the best. Each group member had to draw the same "best parachute" as their final drawing. Both drawings were done to provide a visual representation of what had been made rather than to explore or generate ideas. Thus, they were done carefully and over a long period of time rather than quickly and spontaneously. Although later drawings included both images and words, they were clearly representational rather than conceptual.

The first drawings made by each pupil of his or her own individual parachute could be categorized as elaborating and refining drawings.

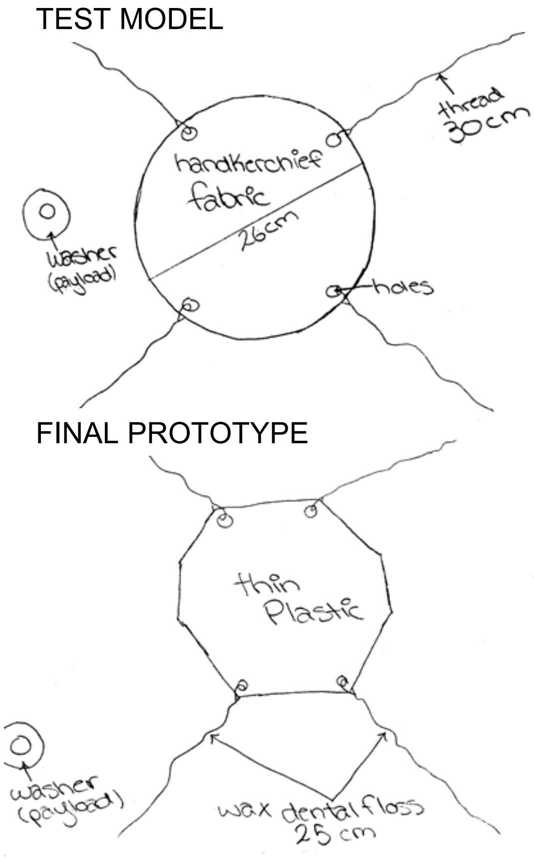

Figure 1. First Drawing Sample

This is because each pupil made a subsequent drawing of the group's single best parachute as a final drawing. At the same time, the first drawings also lacked most of the characteristics of the elaborating and refining drawings, as outlined in the analytic scheme and clue structure.

Each child made a single drawing of her or his own parachute. They then made a second drawing of the final parachute, which was, except in the case of the child who originated it, a parachute other than their own. Thus only in the case of one group member could the drawings be called part of a series (Clue A). The drawings of the individual and final parachutes were not shared with other members of the team except in an incidental way, for example, if a child wanted to show another child what he or she was doing (Clue B).

The drawings did not transform or build on the ideas in the initial sketch because there was no initial sketch (Clue C). It could however be argued that the second drawing did build on previous ideas in the sense that the final

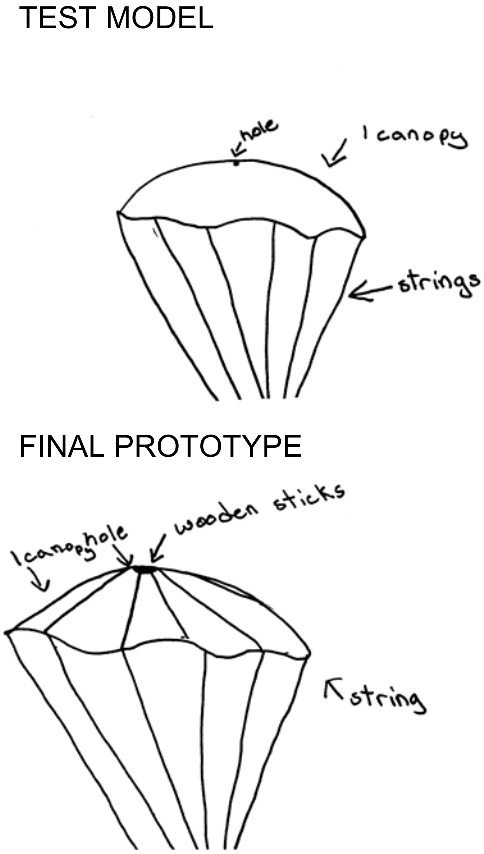

Figure 2. Second Drawing Sample

parachute represented the bringing together of the ideas of the whole group. Because the first drawings marked the end point of the individual parachute building, they did not provide scope for the refinement, expansion, or development of ideas (Clue D), except in the case of the one group member whose parachute was chosen for the second and final test. Finally, as only a single drawing was made, the issue of "increasing accuracy and detail" (Clue E) was a non-issue, except again in a general sense or specifically, in the case of the chosen parachute.

The second drawings made by each pupil were categorized as final presentation drawings. Out of the three categories of drawings, then, the clues for the final presentation drawings most closely matched children's drawings.

The second drawings were made at the end of the project and were a recognizable representation of the finished product (Clue A). Their purpose was to present their parachute to the teacher (Clue B). Most of the final drawings could be used as a guide to creating the parachute that they depicted (Clue C). They were to a large degree finished, although not hard-line in the sense of being ruler-drawn (Clue D). The drawings were reasonably precise and detailed (Clue E). Almost all of them were labeled. Written on the drawings were descriptors such as “circular”, “holes”, “tape”, “string”, and “washers” (used as weights). Although the final drawings were not measured, some indication of proportionality was evident. For example, the sides of square parachutes were approximate equal in length and round parachutes were approximately round.

Discussion

Testing the Analytic Scheme

One purpose of the analysis of the drawings was to test the analytic scheme and clue structure for goodness of fit to the events of classroom teaching. The criteria are twofold (MacDonald, 1995):

1. Comprehensiveness and plausibility of the entire scheme for classroom.
2. Correspondence/discrimination of the individual clues to actual events.

The application of the scheme indicated that the framework was comprehensive enough to capture the main aspects of the lesson. In fact, the scheme was too comprehensive due to the limited use of drawing. In terms of what was in the lesson, a better test of at least part of the scheme would be to look only at the features of the third category of drawings, the final presentation drawings.

For the final presentation drawing, (e.g., the second drawings and for some children even the first drawings) the analytic scheme worked well. The clues were comprehensive enough to cover the main features of the drawings. All the clues were present to a degree that suggests they have plausibility for viewing classroom teaching events. For the overall lesson, the clues were also sound in that they discriminated instances of final presentation drawings from the other two types of drawings, as well as clearly indicated the absence of any drawings that had the characteristics of and fulfilled the purposes of initial sketches.

As in all studies, the selection of a teacher and the lessons was an issue. The test could have been performed using a lesson that incorporated opportunities to create the three categories of drawings described in the analytic scheme. At the same time, the literature suggests that the lesson analyzed was very representative in that the use of drawing was typical of many classroom design technology lessons (Anning, 1997; Fleer, 2000; Hope, 2000; Rogers, 1998; Smith 2001). Further, the application of a thoughtfully developed analytic scheme and clue structure to most lessons can generate useful insights about teaching and learning, as well as suggest guidelines for future research.

The teacher did not make very explicit the purposes of both kinds of drawings. In fact, the instructions to complete the drawings were almost cast as asides. But the timing and characteristics of the drawings indicate that their main purpose was to serve as records of the pupils’ products. The drawings were made after the individual and group parachutes were completed and they were diagrammatic in nature, i.e., representational and labeled.

The initial thinking sketches were conspicuous by their absence. Drawing was conceived in this lesson solely as representation. It was not used to indicate initial thoughts, explore and conceive ideas, or as a vehicle for thinking but was used exclusively to depict the completed product. A balance was lacking between the two ways in which drawings are commonly used in professional practice, e.g., as representation and as a tool for thinking.

The importance of this finding lies not only in its contradiction with professional practice but in its significance for how the parachute task was implemented in the lessons. It is reasonable to assume that there may be links between the absence of the initial sketches and the implementation of the lesson because the task was chosen, set, and taught in a way that excluded initial sketching as an impetus for visual thinking. It is to these three contextual matters that we now turn.

Choosing Tasks

The task here was to make and test a model parachute. Design technology tasks are many and varied as any search of curriculum materials demonstrates. If pupils are to use initial sketching and subsequent drawings to generate and refine design ideas their tasks need to have the potential for a variety of designs. If the tasks have a very narrow range of possible solutions there is little need to create idea-generating sketches.

It is instructive, then, to look at the nature of the task itself as one aspect of considering how drawing was or could be used during design technology lessons. What kind of a task is making a parachute? A starting point is to observe that the modern-day parachute still resembles the one designed and drawn by Leonardo da Vinci in 1485. In fact, a recent test shows that a parachute built according to da Vinci's design could actually carry an individual safely to earth!

Why has the basic parachute design endured for centuries? A major reason is that a descending parachute is influenced and constrained by physical forces, including gravity (weight), lift, and drag (friction). The requirement to descend slowly amid the complex effects of these forces restricts how parachutes can be made. A parachute must be stable, light, and of limited area. It must keep its shape and maintain its balance. A means must be included to suspend the load being carried. These requirements place limitations on parachute design, as well as on the materials used to construct them.

Contrast making a parachute with a task such as creating a model shelter for a pet where restrictions of shape, size, and materials are much less an issue. A pet shelter can be of many different shapes, many different sizes, and can be constructed from a great variety of materials. Accomplishing the purpose of providing shelter is much more open-ended than accomplishing the purpose of descending slowly through the air.

It is instructive to note that the majority of the tasks that pupils carry out in design technology fall generally into one of two categories: architectural (aesthetic) tasks or engineering tasks. This distinction may need to be considered more carefully. Most architectural tasks are by nature more open-ended than most engineering tasks (if the engineering products are to be working models). Space can be enclosed by many different shapes and in many different ways, whereas wheels must be round. The differing natures of architecture and engineering suggest there may be more scope for visual thinking in architecture due to the wider number of options.

Setting Tasks

Another important issue in design technology is how the classroom teacher sets the task. In the present study most task setting was done by outsiders such as the absent regular classroom teacher, the other Grade 6 teacher, and the support resource developers who created the unit plans. The regular classroom teacher instructed the collaborating teacher who taught the lesson to follow and implement the two units of study, *Air & Aerodynamics* and *Flight*, as they were laid out in the support resource. This instruction was reinforced by the other Grade 6 teacher whose class was simultaneously doing the same units.

A distinction made by Kimbell, Stables, and Green (1996) is useful here. They place the setting of design technology tasks on a continuum of closed and open-ended. Closed-ended tasks are initiated “under conditions that provide very tight restraints” (p. 41). More open-ended tasks allow pupils to grapple with the challenges of “pinning down the task for themselves” (p. 41). Kimbell, Stables, and Green suggest that what is important to pupils is that they work in the “messy middle ground” (p. 43) between the two extremes.

In the parachute activity, pupils worked at much more at closed-end tasks, allowing them little space for beginning and ongoing sketches or exploratory thought. This, in turn, was somewhat dictated by the constant focus on making the slowest parachute. A more open-ended task would placed value on other aspects of design, such as aesthetics, and would take into account that real parachutes take a variety of forms for a variety of purposes.

Learning Purposes of Tasks

Kimbell, Stables, and Green (1996) also suggest that design technology tasks have two different kinds of purposes, “product purposes” and “teaching purposes” (p. 36-37). Product purposes have to do with what is made, with the product outcome. This purpose is necessary since it is part of the nature of technological tasks to create products.

Teaching purposes have to do with using the task as a vehicle for teaching something to pupils, such as conceptual knowledge, manipulative skills, technological problem-solving processes, appropriate attitudes, and/or group working styles (Kimbell, Stables, and Green, 1996). This purpose is necessary because classroom situations aim at learning rather than production for its own sake. In the parachute activity, for example, pupils could have learned more about the role of drawing in technological problem-solving, as well as that sharing and discussing each others' drawings is a an appropriate group working style.

McCormick and Davidson (1996) state that there is often a tendency for product outcomes to exercise tyranny over teaching purposes and to take over the lesson. This would seem to be the case in the parachute lesson, with the overwhelming focus on creating the best parachute, i.e., the parachute having the slowest descent. This is what was rewarded and valued rather than the processes of thought leading to the final product.

The tyranny of the product purpose can override the teaching purposes. For example, in the parachute activity, some pupils misrepresented important conceptual knowledge about parachutes. Real parachutes have a hole in the top to make them more stable as they descend. But in the context of the product competition for the best parachute, some pupils deliberately omitted the hole to make their parachute descend more slowly.

Conclusions and Implications

Visual thinking is an important component of design technology but is often relegated to a minor role in classroom practice. Drawing in classroom design technology tends to emphasize representation over ideation. This is reinforced when design technology tasks are limited by nature, set in a restrictive manner, and emphasize product purposes over teaching purposes. Classroom interventions relating to the teaching of drawing and the teaching of design technology could redress this imbalance.

If teaching interventions can enhance pupils' abilities to use sketching not only as representation but also as a means of generating and thinking about design ideas, then the question becomes, "What types of interventions might be useful?" One possibility is to organize lessons around a framework that explicitly integrates the three types of drawing mentioned with the commonly identified phases of design technology problem-solving. A possible model is shown in Figure 3.

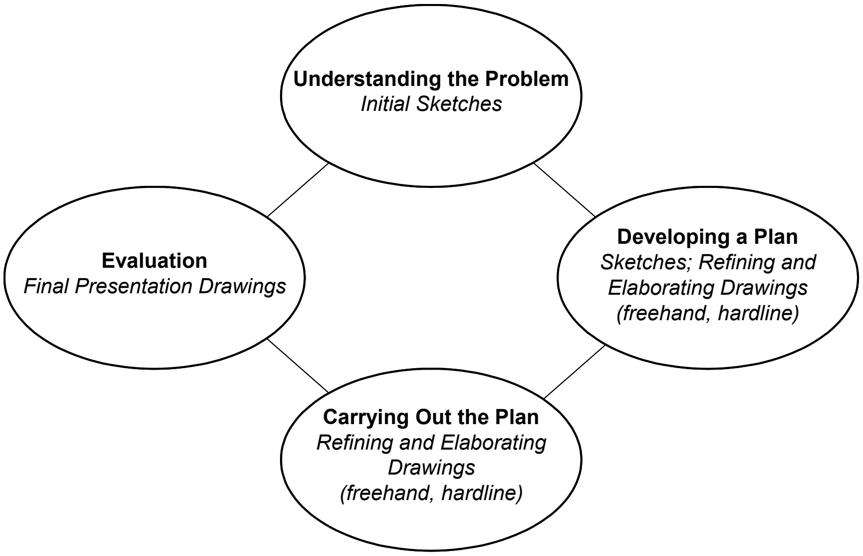

Figure 3. Integrated Drawing/Design Technology Problem-Solving Model

In the clue structure, each drawing is identified with an approximate time period in relation to the carrying out of the design technology project. Thus, each drawing can be mapped on to a different phase of the design technology problem-solving model. The use of such an integrated model could not only explicitly incorporate drawing but also influence the three important contextual issues noted in the study: choosing tasks, setting tasks, and framing the learning purposes. To accommodate the drawing component, the chosen tasks would need to:

- Allow scope for the meaningful use of drawing as an aid to planning and building.
- Be open-ended in regards to the potential solutions that could be developed through visual thinking.
- Incorporate learning purposes beyond the product purpose, e.g., include teaching purposes such as conceptual knowledge, manipulative skills, technological problem-solving processes, appropriate attitudes, and/or group working styles.

The analytic scheme and clue structure used in this study, derived from professional practice, proved useful in analyzing the use of drawing in a classroom design technology lesson. Although the chosen lesson utilized drawing in a limited manner, this was also typical of current design technology teaching. Notwithstanding, the analysis still generated useful insights, as well as provided a basis for a proposal as to how to explicitly integrate design drawing into design technology in a more meaningful way. A future research project could test the classroom use of the integrated drawing/design technology model depicted in this paper.

The notion that the purpose of design drawing is solely to represent objects is likely a common misconception outside the design world. This is true among curriculum developers, teachers, and pupils. Professional development initiatives are important here and can help to broaden the perspective of key stakeholders. The literature on constructivism and conceptual change teaching may be helpful, for example, in starting the process of change by bringing to light prior conceptions about the role of design drawing. At the same time, this need to know even more about the subject matter puts an additional responsibility on overburdened elementary school classroom generalists.

An overall guiding notion for the use of drawing in design technology is balance. In classroom design technology there needs to be balance and ongoing dialogue between drawing as representation and drawing as ideation, between closed-endedness of tasks and open-endedness of tasks, and between product outcomes and teaching outcomes. Through balance, both teachers and students can experience how different types of drawings enrich the representation and generation of ideas during the problem-solving process. Using drawings as a tool to enhance visual thinking can help students both improve their design technology performance and to become more aware of design technology practice in the real world.

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Editorial

Technology Education and History: Who's Driving?

John Pannabecker

Standard 7 of *Standards for Technological Literacy* calls for understanding "the influence of technology on history" (ITEA, 2000 [hereafter *STL*], p. 79). Standard 7 and its *STL* narrative are a curious mix of myth and outdated historiography (the way history is conceptualized and written). Even more problematic, they imply a perspective that is inconsistent with the basic assumptions of technology education as expressed in Standard 6, which focuses on the "role of society in the development and use of technology" (*STL*, p. 73). Standard 6 focuses on humans' active role while Standard 7 avoids humans' active role in favor of how technology influenced history. Why are standards 6 and 7 so opposite in conception? What difference does it make? How could we redesign Standard 7 to reflect an active human role in history?

In this essay, I argue for historiographic approaches that emphasize how people designed and constructed technology, including technological education, in their own contexts in the past. From a historiographic perspective, such historical accounts of the challenges that our predecessors faced in their own contexts will be significantly different from accounts of the effects or "influence of technology on history" as stipulated in Standard 7.

Evaluating Standard 7

According to the narrative of Standard 7 in *STL*, "history has seen at least three great transformations that were driven by technology" (*STL*, p. 79). Standard 7 suggests that the focus should be on technology—some artifact, process, or force out there that has been a primary influence on history. Standard 7 further implies that people do not "drive" technological change, even though the design and abilities standards (8-13) are concerned with how people design and construct technology. This history is segmented into "at least three

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great transformations" or "revolutions" (agriculture; industrial age; "powerful computers and high-speed telecommunications networks," p. 79) as well as other periods such as the "Stone Age," "Bronze Age," "Iron Age," "Industrial Age," and "Information Age" (pp. 57; 86-87). Within these periods, the *STL* narrative locates a sequence of selected great men, events, and artifacts, and the "inventions and innovations...that produced the world as it is today" (pp. 79; 86-87).

The apparent point here is that history is a heroic account of the progress of technology. As a result, "children were not needed on the farm and could stay in school longer" during the Industrial Revolution (p. 87). Eventually, digital artifacts "led to an explosion of computers, calculators, and communication processes to quickly move information from place to place" (*STL*, p. 87). Historians of technology often criticize "heroic" historiography for its failure to recognize the challenges that people of the past faced in solving problems in their own contexts. This "heroic" view also reinforces a "presentist" ideology that implies that the past should be interpreted in terms of the present rather than in its historical context.

There are other problems inherent in this narrative—it portrays the Industrial Revolution as a celebration of America's leadership of technology in the world, starring Eli Whitney's interchangeable parts and Henry Ford's movable conveyor (p. 87). Yet, several decades of research have demonstrated the mythical status attributed to Eli Whitney, who did not invent the principles or practice of interchangeable manufacturing (Alder, 1997; Hounshell, 1984; Smith, 1977; Woodbury, 1959). More problematic is the assumption of American superiority implied in *STL*—an effort associated with an organization that promotes itself as "international."

In contrast, an approach to history that is consistent with Standard 6 would differ in two important ways from Standard 7 in that it would emphasize *historical context* and *humans' active role* in history. In referring to these two characteristics, I will use the terms "contextualist" and "constructivist" respectively. Students would learn how individuals and social groups developed and used arts, crafts, tools, systems, and technologies to solve problems in their own contexts (for more on constructivist approaches, see Bijker, Hughes & Pinch, 1987; Bijker & Pinch, 2002; Clayton, 2002). This approach to history would also be more consistent with the design and abilities standards (8-13). Moreover, grades 9-12 would be less oriented to memorizing dates and lists of great men, events, and inventions, or end products, impacts, or effects. Instead, they would focus on the real struggles that people experienced in designing, constructing, and using technology in their social and cultural contexts.

STL authors made a small attempt to support a constructivist, though not contextualist, approach in K-8 by including hands-on activities and combining multiple standards (*STL*, pp. 80-84). But the vignette selected to support Standard 7 (*STL*, p. 82) is an example of how teaching can distort history and contextual meaning. (The problem here is not so much the vignette itself as the authors' selection of it for this particular context.) In that vignette, Mr. S realizes that his students had never heard of the railroad telegraphers' Morse code as covered in the lesson on Westward expansion. As a result, Mr. S designs activities around the theme of communication, with each group of students focusing on different forms of technology in different time periods. Telegraphy is thus inserted into a timeline of "heroic progress" from drums to telegraphy to email, thus implying that today's technology is inherently superior.

In an approach that is constructivist and contextualist, students would study how individuals and social groups designed, developed, and used telegraphy in its historical context. Each group could research an element of the time, from telegraphy and railroads to agriculture, national and local politics, Native Americans, and immigrant populations, to create a contextual picture of their interaction. The students might also contrast the pros and cons of technologies competing with Morse's system. Students would thus learn how different groups interacted and contributed to the design and construction of technology, including conflicts, challenges, and failures. As a result, technology education would go beyond outdated historiography, myths, and national chauvinism that distort our understanding of the development of technology.

Hidden Assumptions and Problems of the Ideology of "Effects"

A Platonic model seems to undergird *STL*—a model that portrays "the design process" as systematic, controlled, and harmonious, despite occasional failures, "bad effects," or a sporadic nod to multiple design paths. It is perhaps appropriate for the design and abilities standards (8-13) to minimize the role of conflicts and politics, but a history standard should recognize social complexity. In acknowledging the role of conflicts and politics in developing and using technology, I am certainly not suggesting that *STL* should promote conflict.

But our standards should reflect recent historical work that recognizes factors such as conflict, constraints, and contingency as well as teamwork. Designing and building technology is often a messy endeavor. Contingent aspects (chance, uncertain conditions, and accidents), conflicting human choices, and power relationships (politics) play a critical role in technological change. An awareness of contingency counterbalances deterministic interpretations. Yet Standard 7 and its narrative do not communicate this complexity. The fixed structures, rigid divisions, and canon of heroic inventors convey the sense that technology was a highly determined, linear, and predictable enterprise of successful inventors and artifacts.

Historiography can further clarify hidden assumptions in the standards. For comparative purposes, the research and writing of history can be considered internalist, externalist, or contextualist (e.g., Staudenmaier, 1985). Internalist accounts (now rare in *Technology and Culture*) focus primarily on the insides or internal workings of technology, with little reference to social context. Externalist views (e.g., from the standpoint of political or economic history) treat technology from an outside perspective, emphasizing its effects on society, with little interest in how it actually functioned or how people designed or constructed it. Contextualist views consider the development and use of technology in historical context. Standards 4, 5, and 7, which are articulated in terms of the effects or influence of technology, tend to promote an externalist view focused on the use of the completed artifact. As a result, students are likely to focus not on historical *development*, but on the finished artifact and its *end use*—a view similar to externalist views common in traditional history courses.

The artificial separation between development and end use of technology has concerned me since the early 1990s when I argued against the expression "impacts of technology on society" as the sole metaphor in technology education for representing relationships between society and technology (Pannabecker, 1991). Substituting "effects" or "influences" for "impacts" changes little. Contextualist, constructivist historical approaches to understanding relationships between society and technology are more consistent with the field's emphasis on teaching students to design, construct, and use technology. However, the dominant tone of standards 4, 5, and 7 is externalist, focused on "effects." Why does *STL* promote this view?

Technology Education, Engineering, and the Ideology of "Effects"

In the 1980s, changes in name and content from industrial arts to technology education contributed to a sense of ambiguity about the field's heritage. Some teacher educators, myself included, shifted away from a focus on teaching the history of practical education (e.g., Bennett, 1926, 1937; Barlow, 1967) to the history of technology such as told by DeVore (1980). We spent years retraining to include in our courses the history of technology and how technology relates to society, and we expanded the content of our lab courses. That shift towards a broader understanding of technology was invigorating, even as it apparently triggered a decline in the field's reflection on how people designed and constructed practical education. Meanwhile, members of the Society for the History of Technology (SHOT) produced a considerable body of research in *Technology and Culture*. Professional historians increasingly outnumbered engineers in SHOT, and historiography changed markedly since DeVore's *Technology* published in 1980.

In the 1990s, technology education strengthened ties with science and engineering and some of their professional groups became more involved in designing new standards for technology education. While they made positive contributions, they also introduced a new imbalance. For example, the engineering community has never been widely viewed as a leader in general education or in articulating historical methods.

Historically, the engineering profession has often been identified with business and active political influence in controlling technology—not a balanced perspective for interpreting how technology relates to society. Edwin T. Layton's (1986) *The Revolt of the Engineers* remains one of the best historical accounts of the tensions among engineers over social or public responsibility versus loyal service to business and employer. It is noteworthy that Layton's (1974) article on "Technology as Knowledge" is cited in *STL*, but his (1986) *The Revolt of the Engineers* is not. This prompts the question: how did engineering groups influence *STL*?

Greg Pearson's recent editorial in *JTE* (2004) provides some context. He recognized explicitly that "engineering has for years—decades, in fact—been engaged in a campaign for public recognition" (p. 67). He noted that the teaching profession is ranked by the public as higher in prestige than engineering, and that one of the reasons engineering is not well understood is its near absence in US K-12 classrooms (pp. 67-68). Pearson clarified engineering's influence on technology education, and its standards in particular, when he noted: "The NRC review group, chaired by Wulf [president, National Academy of Engineering] himself, proposed a number of substantive changes to the standards' content and organization, and the ITEA managers of the standards project, Bill Dugger and Pam Newberry, adopted nearly every one" (p. 72). The general adoption of these changes suggests that engineering perspectives probably played a greater role in designing the standards than did other professional groups except perhaps science-related groups.

How might the influence of engineering relate to the ideological emphasis on the "effects" of technology in *STL* standards 4, 5, and 7? By designing these standards around "effects," the development of technology can be separated conceptually from social values, thus reinforcing the evaluation of technology as "end result." The artifact can then be controlled and fixed by engineers. It might be government agencies that employ engineers to evaluate the technologies and recommend "fixes," but engineers remain in control of fixing, redesigning, or retrofitting the technology. This approach contrasts with an instructional model that integrates social conscience or responsibility within the design and construction process, and that sanctions the expression of critical reflection (such as "whistle-blowing") for both engineers and the public.

Instead, *STL*'s dominant tone is one of implied neutrality, but with the "engineer in control." Although ethics is mentioned a few times in the *STL* narrative of standards 8-13 (pp. 97, 98, 104, 111), it is clearly not central to the standards of design and development. This is subtle politics that isolates the discourse of social responsibility from the design and construction process, focusing social responsibility at the end use, or "effects" stage. Historians labor to uncover and understand these kinds of politics, the study of which should be included in teacher preparation and graduate programs in technology education. (For an extended discussion of the ideology of engineering, see Layton, 1986, pp. 53-78.)

The assumptions undergirding Standard 7 are now clearer. In the *STL* view, technology is conceived as an "end-use" artifact that has had "effects" on history. The student's view is essentially externalist, possibly with a hint of context implied by Standard 6. Students learn very little about the struggles, debates, conflicts, and challenges of the designers and makers of technology, nor its context, except as "effects" and placed within an artificial period such as "The Iron Age" (p. 86). By the end of grades 9-12, students will have absorbed a canon of selected successful inventors and technologies, placed in their proper "period."

Other interpretations of the "effects of technology" metaphor are possible. For example, some engineering groups have tried to respond to criticisms of their weak coverage of ethics. One of the most common approaches, as reflected in *STL*, examines the social effects or impacts of technology, but that approach remains ambiguous. Indeed, where does one study ethics, values, or "effects"? In contextualist historical case studies? As hypothetical case studies? In the design or implementation stages of engineering practice? Under whose management, and in whose interests?

Fortunately, Hill's (2004) collection of essays provides some guidance in modeling ethical thinking at various stages: design, development, and end use. The collection has at least two major limitations, however: the chapters are generally ahistorical and they lack richly documented narratives and analyses of actual practice, either in technology or technological education. In other words, the authors provide a multitude of rational ideas, models, hypothetical scenarios, and references, but few if any in-depth, contextualized narratives of the real struggles and challenges of human beings. Indeed, our field tells few stories and we lack a heritage of storytelling. Such stories of real-life people and experiences can provide both teachers and students with a richer context for discussing and debating ethics in regard to technology. But *STL* configures history not as critical, richly documented historical inquiry, but as simplistic, uncritical thinking—exactly the opposite climate required for teaching ethics.

Contextualizing the Heritage of Technology Education

Contextualizing the history of technology education is critical for teacher preparation and graduate programs. Otherwise, the field risks a continued decline in its capacity to think critically, research, and teach about the relationships between technology and society. I present the following three themes as examples of how the heritage of industrial arts and technology education intersects with the heritage of other forms of technological education such as engineering education.

Representing and Systematizing Technology

Technology education has a rich historical tradition, including mechanical, manual, and industrial arts. But its expanded scope of content, emphasis on design, and increased links to engineering contribute to a more complex heritage that we need to understand better. For example, the increased emphasis on design in engineering is relatively recent. Wunsch (2002), in his discussion of engineering standards EC 2000, stated that "engineering design, not a part of the curriculum until a generation ago, is now a prime focus of ABET" (Accreditation Board for Engineering and Technology).

Yet systematic design has a rich heritage and industrial arts and other practical arts have distinct traditions of representing and systematizing technology for instruction. In the United States, the introduction of systematizing instruction was typically attributed to the "Russian system" of tool instruction of the 1860s and 1870s (e.g., Bennett, 1937, pp. 13-52; Martin & Luetkemeyer, 1979, pp. 25-26; Kliebard, 1999, pp. 3-13). According to that view, the "Russian system" stood in stark contrast to disorganized, inefficient apprenticeship methods of instruction. As a result of its sudden adoption in the United States and much publicity, the "Russian system" took on a mythical status—not unlike Eli Whitney's "invention" of interchangeable manufacturing. In fact, the developers of the "Russian system" borrowed from other European efforts to represent and systematize practical knowledge in tools, texts, and pictorial representations.

Historians of technology have recently shown more interest in how people developed and used drawing systems, in part because those systems were a means of linking very different types of functions such as design, production, social control, and marketing. While some of the development of design systems occurred outside of schools (e.g., Brown, 2000; McGee, 1999; Pannabecker, 1998), educational institutions played a role in modifying and integrating drawing systems for design, production, and marketing (Pannabecker, 2002, 2004).

Beyond the technical sides of drawing and design, this recent research emphasizes the importance of historical contexts—how different groups and countries developed competing systems of drawing. In addition to representing and systematizing knowledge, drawing was also used to organize and control people through new social hierarchies. Its expanded use in industry and education correlated with growing tensions between workers and management, as well as the spread of political democracies and industrialization. By studying contextual history, technology teachers can develop their ability to understand social interaction, hierarchies, and politics as they relate to technology.

Integrating Math, Science, and Technology

Current efforts in technology education to integrate math, science, and technology also have an extensive heritage, although much of that heritage has either been neglected or ignored. For example, teachers who taught navigational practice in colonial America integrated complex knowledge and artifacts (Fee, 1938, p. 59), as do teachers who now teach geospatial technology systems (e.g., Reed & Ritz, 2004). Yet we have few well documented and contextualized stories of teachers and their struggles to integrate math, science, and technology.

Seeking and telling some of those stories became a challenge for me, which intensified after I started working through the archives of the School of Arts and Crafts of Châlons, France. That School was the first of eight similar schools that now produce the largest number of engineers in France and maintain partnerships with engineering schools in 23 countries. But as originally conceived under Napoleon Bonaparte, they were industrial schools for integrating theory and practice. The School of Châlons was one of the earliest schools to teach the metric system as well as the design and construction of precision instruments. In this regard, Alder (2002) illustrates a contextualist approach for understanding the implementation of the metric system and the practical use of precision instruments. In that story, two French astronomers struggled from 1792 to 1799 to determine the natural length of the meter by measuring the meridian from Dunkerque to Barcelona.

Those astronomers used the repeating circle, an instrument that minimized weight and optimized precision in navigation and surveying, which was developed by Charles Borda in the late eighteenth century. Yet few people know that by 1810, teachers and shop foremen were teaching high-school age students to understand, draw, and construct Borda repeating circles at the School of Châlons. Moreover, that School marketed those student-made instruments to engineers in northern France for the purpose of surveying and road and bridge construction (Pannabecker, 2002, 2003, 2004). In the 1820s, however, as the School's staff sought to integrate math, science, and technology, it encountered enormous resistance from the right-wing government that opposed the transfer of "advanced" knowledge to working class students. The School's experience highlights the challenges that teachers faced in integrating math, science, and technology in the broader social, cultural, and political context.

Despite the considerable potential for historical research in the field, I remain puzzled by a paradox confirmed by my years of teaching lab and shop courses—many teachers in our field have well developed storytelling abilities, but we seem to have a sparse written account of our heritage. There are certainly exceptions, such as Tom Hull, editor of *Quarter Inch Drive*, now at issue 40 and counting. (See also his article related to the cover of *Technology and Culture*, Hull, 2003.) Tom and other teachers, graduate students, and teacher educators should be encouraged by the profession to help develop a written heritage of constructivist and contextualist history.

General Education

The place of technology education in general education should be a central issue for the field and understanding the heritage of our field is critical to navigating the politics of general education. In this regard, industrial arts and technology education have several claims that engineering does not have: (a) an historical though often ambiguous place in both K-12 and general education distributions; (b) a non-elitist outlook and reputation; and (c) a rich heritage of recognized figures in the history of education such as J.-J. Rousseau, Johann Pestalozzi, and John Dewey who made compelling arguments for the importance of hands-on skills in child development. The American Industrial Arts Association (AIAA) often emphasized the place of industrial arts in general education, in contrast with specialized, professional, occupational, or vocational courses.

General education has long sought to moderate powerful instrumentalist ideologies associated with the agenda of business, industry, and the military. If engineering groups start exercising too much influence on technology education, our field risks a greater association with engineering's vocational or professional orientation, its perceived loyalty to business, and its traditional political alliances. Indeed, the heritage of engineering is heavily marked by its loyalty to business, often "big business" (Layton, 1986), as well as military education and priorities. Historically, those associations have not lent credit to a role for engineering in the general education of children. Moreover, the illusion of neutrality in engineering design tends to obscure subtle politics, thus implying greater challenges in teaching human freedom, rights, and choice in design contexts (see, for example, Petrina, 2003, p. 73).

In contrast to engineers, teachers of industrial arts and technology education have been considered non-elitist, and important threads in our heritage have been countercultural. For example, movements such as "arts and crafts" and Sloyd, and figures in the history of education such as J.-J. Rousseau, have strongly marked our heritage as closer to the arts or cottage industry, if not in explicit conflict with industrial production and big business (e.g., Martin & Luetkemeyer, 1979, pp. 27-8). That non-elitist, countercultural side of our heritage positioned our field well in general education. Abandoning that heritage in favor of a stronger, uncritical ideology of engineering presents a weaker argument for our place in general education. Our teacher preparation and graduate programs need to provide students with the complex and sophisticated analytical tools for understanding relationships between technology and society in the past and the present and for negotiating our place in general education.

Conclusion

Without disciplined reflection on the past and associations with influential and diverse groups beyond science and engineering, the field of technology education will not be able to provide its teachers adequate tools for understanding relationships between technology and society in the past and present. Historical analysis can help develop a professional capacity for understanding the role of human choice and freedom in technology and education. Contextualizing our heritage can improve critical thinking if we teach stories of how people designed and constructed technology in their own contexts. We must avoid teaching a simplistic ideology of "effects" and a timeline of decontextualized artifacts and processes portrayed as a canon with a predictable, linear trajectory. Such teaching reinforces a deterministic view of history that makes it difficult to instill in students the importance of human choice and responsibility in design decisions. Teaching a contextualist heritage will increase the field's capacity for reflection and analysis, and for designing standards that are flexible and that stimulate interest in alternate choices. As a result of changing from an "American" (AIAA) to an "International" (ITEA) orientation, Americans need to make a radical reassessment of what it means to be a professional who looks beyond narrow American nationalism.

The following recommendations are directed to all members of the profession in hopes of reviving an interest in our heritage and our capacity to communicate it to future teachers.

1. Modify standards 4, 5, and 7 to be more consistent with the "constructivist" view of Standard 6 and to include contextualist analysis. Example of a revised Standard 7: "The different ways that people designed, constructed, and used technologies in their historical contexts."
2. Build the capacity of teacher educators, teachers, and student teachers to understand the complex dynamics of society and technology in historical contexts, and to make compelling arguments for technology education as part of general education. In order to do this, engage with diverse professional groups beyond science and engineering.
3. Promote storytelling and written accounts of our heritage that include contextualist, constructivist interpretations, that stimulate reflection on ethical decision-making, and that show how overlapping communities of practitioners (e.g., shop foremen, workers, engineers, scientists) contributed to the design, construction, and use of technology in historical contexts.

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