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From the Editor

Integrity and Conscience among the Saber-tooth Tigers

The impact of the economic recession on our field and our lives in general continues. There is increasing evidence that much of this crisis was caused by personal or corporate greed. Dishonesty and self-serving behavior has seemingly permeated our entire society, from the government to religious institutions. As a child I was taught that once we violate a person's trust, it takes ten acts of trustworthiness to make up for it. If we violate trust again, then 100 acts are required, and so forth. There is a lot of truth to this maxim. Unfortunately, the conditions may never arise for the offender to show trustworthiness in the future, thus destroying the integrity of the person or organization forever.

In my own dealings over the past four or so years, I have gone through five automotive repair companies with whom I will never do business again. I have dealt with an improperly prescribed medication, the results of which could have been very grave. I helped an elderly neighbor (that is, more elderly than I) obtain a refund of several hundred dollars for work for which he was duped into thinking that he was responsible. I have received mail from marketing companies that design their letters as though they were part of the federal government. Now that I will soon be eligible for Medicare health insurance, I have received a lot of these mailings. Companies put less product in the same size package and then charge the same or even more for it. Earlier this week I saw a product that I regularly use with a label stating that it contained a "bonus of 25% more" product. I checked into it and found that the "bonus" cost 30% more than the original, smaller quantity, version of the product.

One of the things that I have really valued about my education and experience in technology education is its unique, practical value. This is probably true of everyone in this field. I feel that I have gained a lot of technical knowledge and know-how that I have been able to apply to my everyday life. Perhaps more than any other aspect of my teaching career, I enjoy facilitating the development of this knowledge and ability in my students. I feel empowered by what I know and am able to do and I feel very pleased when I can empower my students as well. One of the outcomes is the ability to know when you are about to be duped in the marketplace.

As time goes on, the technological systems with which we interact become more and more complex. Fewer and fewer people understand them and it opens more doors for deception and the erosion of integrity. Part of our responsibility as technology educators is to teach our students to be able to recognize deceptive practices among those who provide our services and products and to confront those companies and individuals who engage in them. That, it seems to me, is one of the unique contributions to society that should be expected of us and one that we can offer better than any other program in the school. As teachers, we can also serve a broader and more assertive role in the communities in which we live as consumer experts and adult educators. Moreover, consumer education is clearly a part of the *Standards for Technological Literacy* and is reinforced as a goal for technology education in the study reported by Ritz in this issue. It would be interesting, though, to try to find out what the students we serve actually know about consumerism, looking at their "experienced curriculum" as described in the article by Ryan Brown in this issue.

Summer for many educators is a time to catch up on things. For me, this usually involves two activities: doing some pleasure reading and organizing the stack of papers and literature that accumulated over the previous school year. I started with the cleanup part, uncovering one of my favorite books. It was a timely find, for it had direct significance to the major revision I am planning for one of the courses I teach. The book is an oldie, published in 1939, and titled *The Saber-Tooth Curriculum*. The author, J. Abner Peddiwell, is a pseudonym for Harold Benjamin who devoted his career to education, serving in a variety of roles. In fact he may have had some direct effect on our field since he served as Assistant Dean at the University of Minnesota and as Dean at the University of Maryland. The book seemed so pertinent to my present day experiences that I decided to reread it once again. As I read, I was compelled to check the publication date several times to make sure that I was not reading an update of the original volume that was newly published.

Peddiwell describes a curriculum developed in a fictitious paleontological era. It consisted of three courses: fish-grabbing-with-the-bare-hands, woolly-horse-clubbing, and saber-tooth-tiger-scaring-with-fire. As the ancient civilization advanced, there became a time when none of this knowledge and skill was needed, but the curriculum continued unchanged anyway. These subjects, even with their total lack of pertinence, were thought to have taken on "magical power" over the years and thus continued to be the core of the curriculum:

> The only subjects which lacked cultural respectability were those which were studied for the practical effect on the behavior of learners. These subjects remained in a suspected and inferior category, therefore, because they did not pretend to have magic power. Thus the only disgrace in the university curriculum was seen to be the disgrace of being practical. (Peddiwell, 1939, p. 85)

After rereading the Saber-tooth, I searched for book online, trying to find a novel that I thought I would enjoy. The vendor with whom I usually do business presents a list of recommendations for me each time I enter their Website. Among the list of recommendations on this particular occasion was a book titled *Shop class as soulcraft* by Matthew B. Crawford (2009). Trying not to be an impulsive buyer, I read some reviews and quickly decided it was a "must have" since it was written, at least in part, about our field *and* the author was outside of our field – an exciting prospect! So I cast my aspirations in fiction to the wind.

Crawford has an undergraduate degree in physics and a doctorate in political philosophy. For a period in his life he was a manager for a "think tank." Ironically, he became disenchanted with his work and eventually bought a motorcycle shop. He wrote:

> Socially, being the proprietor of a bike shop in a small city gives me a feeling I never had before. I feel that I have a place in society. Whereas 'think tank' is an answer that, at best, buys you a few seconds when someone asks what you do and you try to figure out what it is that you in fact do, with 'motorcycle mechanic' I get immediate recognition. (p. 27) [editor's note: "Hmm…"]

He has a deep concern about how the emphasis in education today is increasingly on the preparation of knowledge workers and this emphasis has consequently reduced the opportunities that students have to work with real tools and materials. He stated:

> Anyone looking for a good used machine tool should talk to Noel Dempsey, a dealer in Richmond, Virginia. Noel's bustling warehouse is full of metal lathes, milling machines, and table saws, and it turns out that much of it once resided in schools. Ebay is awash in such equipment, also from schools. Most of this stuff has been kicking around the secondhand market for about fifteen years; it was in the 1990s that shop class started to become a thing of the past, as educators prepared students to become 'knowledge workers.'
>
> The disappearance of tools from our common education is the first step toward a wider ignorance of the world of artifacts we inhabit. And in fact an engineering culture has developed in recent years in which the object is to 'hide the works,' rendering many of the devices that we depend on every day unintelligible to direct inspection. (p. 1)

He stated further that the high level jobs to which we hope our young people will aspire and prepare themselves will inevitably become routinized:

> Much of the 'jobs of the future' rhetoric surrounding the eagerness to end shop class and get every warm body into college, thence into a cubicle, implicitly assumes that we are heading to a postindustrial economy in which everyone will deal only in abstractions. Yet trafficking in abstractions is not the same as thinking. White-collar professions, too, are subject to routinization and degradation, proceeding by the same logic that hit manual fabrication a hundred years ago: the cognitive elements of the job are appropriated from professionals, instantiated in a system or process, and then handed back to a new class of workers – clerks – who replace the professionals. (p. 44)

Crawford is also concerned about treating students without regard for their individuality and unique interests through:

> …the use of drugs to medicate boys, especially, against their natural tendency toward action, the better to 'keep things on track,' as the school nurse says. I taught briefly in a public high school and would have loved to have set up a Ritalin fogger in my classroom, for the sake of order. It is a rare person who is naturally inclined to sit still for sixteen years in school, and then indefinitely at work, yet with the dismantling of high school shop programs this has become the one-size-fits-all norm, even as we go on about 'diversity.' (p. 73)

In Catholic school I learned about the "examination of conscience" whereby you reflected on your transgressions and omissions of responsibility. You also reflected on the good things that you did. After reading these two books, I found myself torn in a dichotomy parallel to that of good and evil, without knowing which is which. It also made me realize once again how grave the responsibilities are for teachers, how different the schools are today than they were when I started teaching, and how much our profession has changed. I also think about how many educational initiatives we have embraced over the years and how much energy and money we put into them. Only a handful had any affect whatsoever in the long term education of the youth we serve. Having been a science teacher for a time as well, I know the same thing is true in other realms of education. Along with some of my colleagues who have expressed the same sentiment over the years, I thought about the integrity of these initiatives. I wondered if they were really only self-serving to advance the careers of the developers, to meet university pressures for acquiring funding and producing publications, to seize an opportunity simply for opportunity's sake, or perhaps even to feed an ego; or did the developers really believe that their work would significantly change our profession for the better? I also wondered about how many very capable individuals in our field have turned their backs on opportunities to contribute through leadership, service, research, and development. I also thought about brilliant projects, like brilliant products, that were never implemented due to the lack of a "marketing plan." Then my thoughts turned to the "curriculum wars" that mark our history, and where the line is between healthy competition and the deterioration of our profession.

I examined my own conscience in this way relative to the endeavors in which I have been involved. I tried to think of these efforts from the perspective of both a producer and a consumer. I also thought about the long-term influence that my projects, including my doctoral dissertation, had on our profession. For the most part, it was a rather disheartening self-examination. At the same time I came to the conclusion that all this sort of work has a hidden result, akin to the notion of the "hidden curriculum." That is, all these efforts toward change bring people together in collaborative discourse, socialization, and the sharing of values and ideas. In the end, these unintended results often become the most significant; they become the planted seeds that yield true, lasting benefits. Just as with the impact that our teaching has on our students, the real legacy of the work we put into this profession rests in the people we serve and with whom we work.

As I continued to reflect about my personal integrity, my mind was flooded with occasions of poor judgment and irresponsibility, especially regarding the students with whom I had worked over the past 43 years. I wondered what lasting damage my treatment of them might have resulted.

When I do this sort of reflection I inevitably end up thinking about a particular special needs student who was not given any attention whatsoever in another teacher's class. I decided to mentor this boy during the last period of the day, my preparation period, by letting him serve as my "lab maintenance assistant." While he was carefully holding a new cabinet door in precise position, awaiting my installation of the hinge screws, I was called to the main office for some mundane reason. On my return I decided to pick up my mail and then stop by the teachers' room for coffee. After coffee and extended conversations with my colleagues, I returned to my lab and decided to call it quits for the day. As I was leaving, I heard a muffled voice calling my name. I rushed to the storage room in which the cabinets were located and there was my student assistant who exclaimed, "I thought you were never going to come back!" As he removed his hands from the new door, there were perfectly formed silhouettes in perspiration of his hands. He had held the doors just as I had instructed for well over an hour! I can only imagine what impact this might have had him. On the other hand, I beamed in concert with him when he showed his parents the cabinet doors during an open house at the school.

A second scenario that inevitably unfolds when I reflect about integrity is set at a university where I taught very early in my higher education career. The dean made a point of meeting with the faculty in each department in the college at least once a semester. Ahead of one particular meeting, that person had been given a copy of a new brochure, describing what industrial arts (the name at the time) was, the wonderful programs that were offered, and how it provided essential experiences for students. As it turned out, the dean had just completed servicing on a task force that visited 50 schools across the state. During the meeting, the dean expressed great admiration for the brochure, but added that none of what was in the brochure was observed in any of the visited schools. There was no intent of deception on the part of the state organization involved – the brochure simply represented the ideals to which the field aspired, but not the reality. Inadvertently, a significant amount of integrity was lost across the state. Though it may have only been coincidental, the program at the university was eliminated just a few months after that meeting.

Seeing "shop class" on the cover of a modern book caused me to pause and reflect about the disdain that has developed for that word within technology education. Peddiwell would likely embrace the word since it represents viable, practical education. For Crawford, that word embodies the heart of what is missing in the experiences that need to be provided to the students we serve. For many in our field, on the other hand, it characterizes the epitome of what we have worked to move away from for several years now. We have tried to "rebrand" our field several times over the years and are in that process right now. If only we could do as well now as was done with "shop" in an earlier era!

I am certainly not in favor of using the term "shop class" and it is amazing to me that it is used as often as it still is. After all, William E. Warner proposed that "lab" be used instead of "shop" during the 1930s. ("Lab class" does not make any sense, though, does it?) However, I can relate to Crawford in the sense that after four years of Latin and two years of Greek in high school and no applied courses, I could not wait to enroll in an educational program with an emphasis on application and practice. After reading his book, though, I did remember how flattered I was to be called the "shop teacher."

Though I will never really know the extent of my influence on my students, good or bad, I can avow with absolute confidence that none was maimed by a Saber-Tooth Tiger. Moreover, neither high-fructose corn syrup nor Ritalin was available back then, either.

JEL

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Articles

Curriculum Consonance and Dissonance in Technology Education Classrooms

Ryan A. Brown

Introduction

In a time of increased accountability, a tightened curriculum, and fewer curricular choices for students, technology education in the United States is in the position of defending itself by "carving a niche" (Meade, 2004, p. 24) in the school curriculum. Justifying the place of technology education is becoming increasingly difficult, as there has been little agreement in either policy or practice over the definition and function of technology education. Within the past several decades, the International Technology Education Association (ITEA) has taken on the task of defining the nature of technology education and has created a series of standards, benchmarks, and curriculum documents that are focused on that goal. As Thornton (1988) noted, however, "curriculum decisions are ineffective unless they affect what teachers do in classrooms and what students learn" (p. 308).

The problem addressed in this study is determining whether the new "official" definition and purpose for technology education has had any effect on technology education classrooms. The concern, and the focus of this study, is that technology education as defined by ITEA might not be what is currently taught by teachers and experienced by students. A gap between the field's conception of technology education and what is actually being taught in the classrooms would not be unusual, as similar disparities were found in math, biology, and physics nearly a decade after new curricula had been introduced in each of those areas (Cuban, 1993).

The purpose of this study was to determine if inconsistencies exist between the field's view of technology education and the events that take place in the technology education classrooms by examining the relationships among the

Ryan Brown (rbrown@ilstu.edu) is an Assistant Professor of Curriculum and Instruction at Illinois State University, Normal.

field's teachers' and students' ideas regarding the nature and outcomes of technology education. This was designed to help bridge a gap in technology education research. Over the years, research in technology education has examined the nature of the technology education curriculum and student outcomes associated with taking technology education courses from the perspective of experts in the field of technology education. Several recent studies have examined the curriculum and outcomes of technology education from either the teachers' or students' perspectives (see Boser, Palmer, & Daugherty, 1998; Foster & Wright, 2001; Taylor, 2006; Volk, Yip, & Lo, 2003; Weber & Custer, 2005). However, very little research has been located that compared both perspectives (see McLaren, 2006).

This study will begin to fill the gap created by the lack of teacher and student voices in technology education literature regarding the nature and outcomes of technology education courses and programs, helping to create a more complete picture of how technology education curricula are utilized by teachers and experienced by students.

Methodology

This study employs the qualitative inquiry method of a collective case study (Merriam, 1992; Stake, 2003). The case study approach was used in an effort to, as Merriam (1992) suggests, "gain an in-depth understanding of the situation and meaning for those involved" (p. 19). A collective case study was designed in which multiple sites were used to "investigate the phenomenon" with the belief that it may lead to a "better understanding of a larger collection of cases" (Stake, 2003, p. 138). Three cases were used because it was believed that combining the cases would lead to a better understanding of the curriculum consonance or dissonance that is present in technology education classrooms.

Settings and Participants

Three Indiana high school technology education classrooms were selected to include "variety across the attribute" (Stake, 2003, p. 153). The schools were purposefully selected to include a range of small to large schools in rural to urban settings, within a specific region (within 50 miles of Indianapolis). The cases were also chosen to include teachers of both genders and different levels of experience. Southern Glen High School was selected first, as it was one of few schools in the region with a female technology education teacher. Southern Glen is a mid-sized school (1,000 students) in a rural setting. Ms. Marshall, the technology teacher, has 23 years of teaching experience. The other two schools were then selected using the Indiana Department of Education website to locate a small and a large school with a male teacher early in their career and one in the middle of their career. A list of teachers and schools was generated and the first teachers on the list, Mr. Theriot and Mr. O'Malley, were contacted and agreed to participate in the study. A profile of the schools and teachers can be seen in Table 1. All school, teacher, and student names in this study are pseudonyms.

Table 1
School Profiles

School	Teacher	Teacher Experience	School Enroll-ment	Depart-ment Size	Curriculum
Three Rivers High School	Mr. Theriot	3 years, as a technology teacher	550	1 technology teacher	Traditional technology education
Southern Glen High School	Ms. Marshall	23 years	1000	2 technology teachers	Traditional technology education and Project Lead the Way
North Side High School	Mr. O'Malley	9 years	1500	3 technology teachers	Project Lead the Way

Conceptual Framework and Research Questions

In order to examine the curricula that existed in technology education classrooms and to compare them to an official curriculum, it was determined that it would be beneficial to focus on specific phases, or types, of curricula. Myriad labels are used to represent a stage of either planning or teaching that occurs along a continuum that begins with a national or district-level set of objectives or standards and concludes in the mind of the students. Throughout this continuum, "transformations occur as curriculum meanings are modified or contested by teachers and students in the context of their own beliefs, experiences, and communities" (Werner, 1991, p. 114). The curriculum continuum was examined in this study through the use of Thornton's (1985) concept of curriculum consonance, which he defined as the "relationships between the intended, the actualized, and the experienced curricula" (p. 9). This notion of examining the curriculum that the teacher intends to teach, the curriculum that is actually taught, and the curriculum that is experienced by students supplied an effective framework for use in examining the nature, aims, and outcomes of the technology education curriculum at various levels within the classroom. However, the relationship between the field's conception of the curriculum and the classroom curriculum was absent from Thornton's concept of curriculum consonance. This study adds the *official curriculum* as a factor in the relationship between the curriculum that exists in the classroom and the one that exists in the teacher's mind.

The research questions were:

1. What is the official technology education curriculum?
2. What are the intended, implemented, and experienced curricula in technology education classrooms?
3. How are the official, intended, implemented, and experienced curricula related to each other? How are they consonant? How are they dissonant?

Data Collection and Curriculum Types

In order to better understand the nature, aims, and outcomes of technology education and to answer the above research questions, the official, intended, implemented, and experienced curricula were examined within both the literature of the technology education field and in technology education classrooms. The data collection methods varied based on the type of curriculum that was being examined and included document analysis, interviews, and observation. A discussion of the definitions of the types of curricula that were examined and the methods used to collect data for these curricula follows.

The *official curriculum* is comprised of the national, state, and district-level standards and frameworks for the study of technology education. In this study, the official curriculum has been determined based on the analysis of standards and technological literacy documents (i.e. Indiana Department of Education, 2004; International Technology Education Association, 2000, 2003; National Academy of Engineering & National Research Council, 2002, 2006), state course guides, textbooks, monographs (i.e. Maley, 1995), and journal articles.

The curriculum that is written into the teacher's plan book is known, in this study, as the *intended curriculum*. The intended curriculum is created by a series of choices that teachers make as they plan their courses. The intended curriculum of each teacher was ascertained primarily through teacher interviews. A semi-structured interview was conducted at the beginning of the research that focused on each teacher's teaching background, concept of technology education, perceived student benefits from their classes, use of teaching and evaluation methods, and beliefs regarding the importance of technology education concepts. The interviews for each teacher were based around a common protocol that allowed for consistency but also allowed for the researcher to ask follow-up and contextual questions. In addition to the formal interview with each teacher, this study was also informed a great deal through informal discussions and conversations with the teachers that took place between classes, before or after school, and while students were engaged in projects.

The *implemented curriculum* is "what teachers actually do in their courses once they close the door of their classrooms" (Schugurensky, 2002, p. 3) and is much more visible than the official or intended curriculum. In this study, data on the implemented curriculum were collected during approximately one month of classroom observations. The researcher spent over 50 hours in each of the three teachers' classrooms and observed at least two courses taught by each teacher. Field notes were recorded that included descriptions, teacher and student comments, the researcher's initial reactions, and questions that arose during the observations.

The *experienced curriculum* consists of "those things that a student chooses to emphasize, elaborate on, ignore, or omit as he or she recounts learnings…the learner's personal meanings" (Rogers, 1989, p. 715). The primary data source used to develop an understanding of the experienced curriculum was student interviews, which helped identify their perceptions of the class curriculum, their definition of technology education, and the expected outcomes of having taken the course. An average of 10 students were interviewed in each of the three classrooms. In some cases, the students were in more than one of a given teacher's classes and were able to speak in regards to several courses during the interview. Like the teacher interviews, the student interviews followed a common protocol that was slightly adapted for each school. Several of the questions posed to the students were based on their teacher's intentions or on specific information related to their course.

Data Analysis

The data that were collected for the official curriculum and each case were sorted into six categories (context, broad educational aims, objectives of specific curricula, curriculum materials, transactions, and outcomes), based on the components of curriculum suggested by Madaus and Kellaghan (1992). The remaining analysis of the data was conducted using a process described by Spencer, Ritchie, and O'Connor (2003) that included managing data, creating descriptive accounts, and generating explanatory accounts. This process included creating an index of main and sub themes, sorting and clustering data, and refining categories. Lastly, patterns were detected and explanations were developed.

Limitations

Several important aspects of this study limit the findings. The sites that were utilized in the study provide a limitation. While they represented different sized schools and different settings, all were high schools within a 50-mile radius in Indiana. Schools outside of Indiana and a greater range of grade levels may have provided different data. The student population was also a limitation. This study examined three varying schools, but the vast majority of students in all three schools were white males. The researcher is unable to report how consonance in technology education is addressed in schools with high levels of minority students and how the curriculum is experienced by minority students. It would also be interesting to learn more about the experiences of female students in the courses. This study did include interviews with at least one female student at each school; however the data were not analyzed in a manner in which the experiences of the female students can be reported with confidence. Lastly, the time spent in the classrooms is a limitation. Spending a larger amount of time in each classroom could have provided greater insights into all levels of curricula that existed.

Summary of Findings

The findings presented here will be focused mainly on the final research question: How are the official, intended, implemented, and experienced curricula related to each other? How are they consonant? How are they dissonant? The official, intended, implemented, and experienced curricula of the three classrooms in this study exhibited relationships that ranged from highly consonant to extremely dissonant.

Technological Literacy

A critical finding is that both consonance and dissonance were found when the concept of technological literacy was explored. It was found that the intended, implemented, and experienced curricula included a slice of technological literacy, using the *Standards for Technological Literacy* (ITEA, 2000) as a framework. Mr. Theriot was the only teacher to specifically mention technological literacy as an intended outcome of his course, stating that he tries to avoid "technological literacy from the Google standpoint," which he describes as focusing on vocabulary, but instead he intends on getting students to use technology to figure out how to solve problems. He believes that will lead to students "becoming technologically literate." While Mr. O'Malley and Ms. Marshall did not use the term technological literacy, they responded to the use of the standards in their teaching.Ms. Marshall, when asked about the influence of the standards, responded that "I figure that I am pretty close on hitting them because I am following the curriculum, [short pause] for the most part." Mr. O'Malley on the other hand, stated that "to be dead honest, I haven't even looked at" the *Standards for Technological Literacy,* but he did claim to periodically look at the state standards to make sure that there is a connection between his curriculum and the standards.

The teachers, while not always focused on technological literacy, did intend to teach content that fits within the *Standards for Technological Literacy* (ITEA, 2000). Ms. Marshall, for example, intended to teach students how to design and create video and printed materials and Mr. Theriot intended to teach students to use telecommunication tools. Mr. O'Malley intended to teach the students how to use the design process. All of these intentions can be found within the *abilities for a technical world*, *design*, and the *designed world* categories of the *Standards for Technological Literacy*.

These three categories were being implemented in all three of the technology education classrooms. Design; problem solving; and content specific to communication, construction, and information technology were the main areas of these standards that were implemented in the classrooms. Throughout the three classrooms, the researcher observed students designing products such as desk organizers and doghouses and creating artifacts such as videos, news programs, and models of homes.

The majority of students reported learning concepts related to these areas of the standards in the experienced curriculum as well. In Mr. O'Malley's class, for example, students were asked about the most important concepts that they had learned in the course and most students' responses involved the design process. Several of Mr. Theriot's students stated that concepts related to problem solving were the most important concepts that they learned in the course. Ms. Marshall's students stated that technical skills (related to video production) were the most important concepts that were learned.

While several aspects of technological literacy were found to be consonant, as described above, several were found dissonant. Of the five areas of the *Standards for Technological Literacy* (ITEA, 2000), the *nature of technology* and *technology and society* were addressed only in Mr. Theriot's curricula, although he stated that he does not use the standards to plan his curriculum. The *nature of technology* and *technology and society* aspects of the standards were implemented as the students were introduced to content such as the systems model, math and science integration, and technology assessment and evaluation. Because these areas of the curriculum were missing from Mr. O'Malley's and Ms. Marshall's curricula, these teachers did not intentionally introduce students to the characteristics, scope, and core concepts of technology; the relationships between technology and other fields; the cultural, social, and economic effects of technology, and the role of society in the development and use of technology. These was evident in student interviews regarding the experienced curriculum, as Mr. Theriot's students were better able to define and give examples of technology than either Mr. O'Malley's or Ms. Marshall's students. Mark and Michele, two of Mr. Theriot's students, defined technology as "the use of all modern inventions and instruments" and "inventions that help us make things easier," respectively. The majority of Ms. Marshall's students either identified technology only as information technology (computers, software, printers, etc…) or simply did not know how to define it. The standards in these two categories represent over one third of the *Standards for Technological Literacy*. Interestingly, however, all three of the teachers believed that they were meeting the standards (even after admitting that they do not rely on them for planning purposes) while even in the intended curriculum they were omitting the majority, if not all, of two of the five categories of the *Standards for Technological Literacy* (ITEA, 2003).

Preparation for the Future

Another consonant theme that cut across all three cases was a focus on preparing students for the future. This theme is also found in the official curriculum of technology education and has been carried over from the industrial arts era (see Zuga, 1989). More recently, it has been stated in official curriculum literature that, "technological literacy is what every person needs in order to be an informed and contributing citizen for the world of today and tomorrow" (ITEA, 2003, p. 10).

While it was not always focused on citizenship, each of the three teachers described one of the aims of his or her course as preparing students for the future in one of several ways. Mr. O'Malley intended to provide students with the background and career knowledge that they would need in the future, Mr.

Theriot intended for students to engage in experiences that they would use in the future and that may help them to select a career path, and Ms. Marshall hoped that students would explore their interests and potential career opportunities.

The researcher found that a number of students reported experiencing content that either they would use later in life or that would help to prepare them for the future. Mr. O'Malley's students, generally, believed that they would use their knowledge of the design process later in life. Mr. Theriot's construction students described that the course helped provide information about career paths. Russ explained that the course was helpful because "you kind of group [construction careers] together when you think about construction, but if you actually think of all of the different ones you get a better idea of construction." Mark stated that he learned "which careers I would like to go into if I go into the field," which included either framing or roofing. Ms. Marshall's students believed that their technology education courses not only helped identify potential careers but also helped to make them more responsible and better planners. Eric, a student of Ms. Marshall, stated that he has become better at planning "because there are so many steps you have to do before a project. You have to make a rough draft, plan it out, get it checked, make your corrections, and then finally you get to start on the main project". He believes this will help him in his future pursuit of a degree in architecture. In implementation, like in the official curriculum, the theme of preparation for the future was not overt, but it was intended and experienced.

Computer Literacy

The final finding is related to computer literacy. While describing the intended aims of their courses, the teachers' in this study did not list computer literacy. Computers were discussed in most of the interviews, but never as the focus of learning. For example, Mr. O'Malley stated that his students "would be learning the software, so that they could apply it" to the design process.

However, a substantial number of students at each of the three schools stated that they gained computer knowledge and skills. Students from all three schools often cited improved computer and software skills as the most important thing they have learned in the courses. Mark, one of Mr. Theriot's students, when asked about what he will take away from the course, stated that it was the "computer software stuff that I am learning, I won't be able to forget that." When Eric, a student of Ms. Marshall, was asked the same question, he responded "I know that I will use all the software and anytime that you want to make a memo or turn in an application, you will use Microsoft Word or for a presentation PowerPoint or Publisher." In all three schools, computer skills were also the main reason that many students took the courses. While it can be argued that computer knowledge and skills should not be the sole focus of technology education courses, the fact remains that students consider this knowledge valuable.

Conclusions

The findings demonstrate both consonance and dissonance within the technology education curricula. The examination of these findings from the three technology education classrooms has led to two main conclusions regarding the consonance and dissonance in technology education curricula: (1) technological literacy and the *Standards for Technological Literacy* are not fully intended, implemented, or experienced; and (2) technological literacy has been subsumed by computer literacy in some classrooms.

Technological Literacy and Standards

Technological literacy and the *Standards for Technological Literacy* are not fully intended, implemented, or experienced. Technological literacy was described as an intention only in Mr. Theriot's classroom, and the components of technological literacy were only partially implemented and experienced in all three classrooms. As described earlier, the areas neglected most were the *nature of technology* and the *technology and society* aspects of technological literacy. All teachers were successful at teaching the *designed world* and *abilities for a technical world* categories of the standards, which were also well covered in the intended, implemented, and experienced curricula of the three schools.

It comes as little surprise that the *designed world* and *abilities for a technical world* standards are stressed most in the classrooms, as they can be seen as the "hands-on" components of technology education. These standards emphasize learning how to use and create technology and are easily shaped into "hands-on" activities and lessons. Skills contained in these standards include processes such as developing a product or system using a design process, using computers in a number of applications, communicating a message, and understanding the requirements of a structure. These components of the standards are commonly found in technology education classes in the form of activities such as designing a CO_2-powered car, using design software, creating a graphic or video advertisement, and designing a house to meet requirements, which were all activities that were observed during this research.

All three of the teachers made statements similar to Ms. Marshall's comment that "the tech. ed. standards are broad enough that you can close your eyes and point to one and almost be guaranteed that you are going to hit it." The teachers were correct. The standards are broad and cover a wide range of content. However, the curriculum that was observed was narrower and only covered several standards. It is true that these teachers, and possibly most technology teachers, hit upon the standards as they plan and implement their lessons. Their lessons, with the exception of several of Mr. Theriot's lessons, always tended to cover the same or similar standards. In Mr. O'Malley's and Ms. Marshall's classrooms, the *nature of technology* and *technology and society* standards were largely untouched.

Mr. O'Malley, Ms. Marshall, and to a lesser degree Mr. Theriot were working under the faulty assumption that they would achieve consonance with the *Standards for Technological Literacy* by using planning resources such as textbooks, course guides, former students, community service needs, and their own experiences. These resources, however, as used by the teachers in this study, do not automatically lead to complete coverage of the Standards. Consider for instance the textbook used by Ms. Marshall in the communication systems course—only three of the over forty chapters cover content related to the seven standards that are included in the *nature of technology* and *technology and society* categories. Even the Indiana Course Guide (Indiana Department of Education, 2005) for the communication systems course lacks content related to these two categories. This study found that only *Unit One: Communication Technology* actually included substantial content from these standards. Teachers could certainly find ways to include this content in the units, as Mr. Theriot did on several occasions, but they are not provided with examples of how to do so.

We are left with several questions. First, as in the case of the communication textbook and course guide, is a minor presence of the *nature of technology* and *technology and society* content enough to conclude that the standards have been covered? This question is at the crux of the standards debate. The standards are not intended to be a curriculum, as they provide neither a scope nor sequence. However, if Ms. Marshall or Mr. Theriot followed either the textbook or the course guide in their communication systems courses, students would have been introduced to information. Such information would include the characteristics of technology, the effects of communication technology, its influences on history, and its role in society at either the beginning or end of the course with little or no discussion of these concepts at the heart of the course. This is a shallow treatment of a major portion of the Standards. But is that acceptable? Should every standard be covered in every course? Is that even possible? Is this a case where dissonance is actually desired?

There are certainly several reasons why dissonance with the inclusion of *nature of technology* and *technology and society* standards may be preferred by the teachers and the students. The first is that this content may be new to teachers and outside of their own backgrounds and experience. It was evident in the research that each teacher's experiences and background had an impact on the content that was taught. For example, Mr. Theriot's has a strong background in computer technology and mathematics that influenced the curriculum that he planned and the way that he understood and taught technological concepts. He was able to infuse mathematics into the curriculum and help students create small computer programs. Technology teachers often have a large amount of flexibility when planning their curriculum since high-stakes tests, at least at the present time, do not determine course content; it is likely that teachers would choose to teach the content with which they are the most comfortable. The second reason is that the content in these two areas is not as easily viewed in terms of "hands-on" activities, the typical instruction method in technology education. It was evident in the research that the teachers wanted students to be actively engaged in the learning. However, topics like the cultural, social, and economic effects of technology, and the role of society and its historical influence, are not easily taught in the same "hands-on" way that can be used to teach students how to use design software or create a structure, vehicle, news program, or advertisement.

This leads me to a final reason that teachers and students may prefer dissonance in this area: based on the research it was found that the students take the courses to use computers and to participate in hands-on projects. In an elective content area, teachers must keep students interested and excited about the course in order to keep enrollment high. Marketing and promotion were certainly intertwined into each technology education program. Teachers used school board meetings, graduation, and display cases to showcase the work that their students were completing to drum up interest and support for their programs. They also used the curriculum and instructional methods to promote their programs. By using hands-on activities, action-based content, and avoiding content that is more conceptual and theoretical, the teachers are in turn marketing their courses as fun, activity-oriented classes where doing and building come before learning and analyzing the entire scope of the standards.

Computer Literacy

The second and final conclusion is that computer literacy is a real and valid experience in technology education courses. This conclusion is not surprising if we were to agree with Petrina's (2003) assertion that educational technology and technology education are one-in-the-same. While that point can be argued, many in the technology education field have been adamant about recognizing the division between technology education, educational technology, and computer education or computer literacy and have also acknowledged that public misconceptions exist over these terms (Dugger & Naik, 2001; McCade, 2001; Weber, 2005). McCade (2001) stated that "technology educators have at one time or another been frustrated by the confusion created by such terms as educational technology, computer technology, or instructional technology" (p. 9). He also stated that while learning about computers has a place in technology education, "if technology educators attempt to claim all of computer literacy, we will not have the time or resources to deliver other important aspects of our content" (p. 9). Computer knowledge and skills can be found in the *Standards for Technological Literacy*, but as McCade (2001) suggested, those skills are only a portion of the content that should be delivered in technology education courses.

In the classrooms studied here, a range of content was delivered; however, the content and experiences that students recognized most were computer knowledge and skill. It is also a reality that many of the students enrolled in technology education classes for that specific purpose, to learn computer skills. Students spent a large amount of time engaged in projects that required the use of computers. Mr. Theriot's students were creating Flash animations and learning to use 3D design software. The students in Mr. O'Malley's courses were engaged in learning to design products using solid modeling software. Ms. Marshall's courses were focused on using computers to edit videos and create graphic designs. Based on the observations of the classrooms, it is realistic to expect students to have experienced computer skills because it was a major portion of the implemented curriculum, often to the exclusion of other content. For example, Mr. O'Malley taught students to use Autodesk Inventor without teaching the concepts behind the skills they were learning. The same was the case in Ms. Marshall's class; as students created banners on Microsoft Publisher, they learned the software but not elements of design. Lewis and Zuga (2005) refer to this phenomenon as teaching students using the language of technology. They provide the following example:

> Without technological language as identified in taxonomies, children are asked to make bridges and they are tested on the physics related to bridges while the technological concepts such as the structure of the bridge and the best means of assembling that structure may be ignored. It is not that the physics of bridge construction are not important, but it is that the technology of bridge construction and the relationship of the technology to the physics through making choices about the best way to construct a bridge is what is important in bridge building. (p. 81)

The case of computer knowledge is similar in that the computer knowledge and skill are important, but so are the underlying concepts for which the students are using the computer (engineering design and graphic design, in these cases). Students reported gaining computer knowledge and skill as part of the experienced curriculum because without the additional conceptual knowledge, the students had only computer knowledge and skills to take away from these activities. For example, at Southern Glen High School, Ms. Marshall created a graphic communications unit that was intended to teach students design elements such as formal and informal balance. However, the implementation of the unit stressed the use of Microsoft Publisher and students were unable to describe graphic design elements such as balance. The same was the case in Ms. Marshall's video production course, as students created digital movies with a focus on iMovie and little, if any, instruction on the elements of a quality movie. Likewise, in Mr. O'Malley's classroom, the students learned how to use the features of Autodesk Inventor without gaining a conceptual knowledge of the features they were using.

This conclusion is particularly interesting when examined alongside the financial aspects of each school. The three programs represented a wide range of funding. Mr. Theriot at Two Rivers High School was faced with providing a full line of technology education courses while mainly relying on outdated computers, mismatched video technology, a sparsely equipped laboratory area, and a budget of only one hundred dollars per course for the entire school year. It was observed that Ms. Marshall had newer computers and video equipment, although she was limited in making other purchases, as they sold food to raise money for the department. North Side High School had the newest computer technology and ample funds to purchase supplies and equipment. Full implementation of the standards and technological literacy was found to be inversely proportional to the age of the computer technology and the amount of available funds. In the schools with newer computer technology, all aspects of the curriculum were more focused on computer literacy rather than technological literacy. This finding demonstrates that in these three classrooms computer technology does not necessarily lead to greater technological literacy and greater implementation of the standards.

Implications for Further Research

Each of the conclusions leads directly to additional questions for further research and closer examination. Additional studies are needed to examine the curriculum in technology education classrooms over a longer period of time to determine whether or not the missing content might be present at other times in the semester. Further research is also needed to determine why content such as the nature of technology and connections between technology and society were the areas that were largely absent from the curriculum. It is important to determine the impacts and consequences of the focus on marketing and whether it overshadows curriculum, and to examine why students see computer literacy as a more valuable learning experience than technological literacy.

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Technology-Based Content through Virtual and Physical Modeling: A National Research Study

Jeremy V. Ernst and Aaron C. Clark

Introduction

Visualization is becoming more prevalent as an application in science, engineering, and technology related professions. The analysis of static and dynamic graphical visualization provides data solutions and understandings that go beyond traditional forms of communication. Ahern (2007) asserted that development of visualizations through analysis exceeds simple generation of imagery and incorporates data exploration, visual code debugging, comparative analysis, quantitative analysis, and presentation graphics. Evidence of this is seen by current visualization projects at The National Center for Computational Sciences that cover a wide range of application areas including astrophysics, material science, climate dynamics, fusion, and turbulent combustion.

The use of visualization to convey scientific/technical content and research enhances viewers' abilities to identify and retain significant information that is not as straightforwardly permitted through traditional mediums (Bomphrey, 2006; Payri, Pastor, Garcia, &Pastor, 2007). Visualization allows for complex processes, often involving multiple models, scales, and disciplines, to be represented in a clear and direct manner (Schuchardt, Black, Chase, Elsethagen, & Sun, 2007). Visualization-based content through electronic representations highlights important features and processes that can be used for experimental verification (Debowska, Jakubowicz & Mazur, 1999). Scientific visualization allows investigators to construct meaning from large amounts of data (Robertson, Mackinlay, & Card, 1991). Meaning is constructed by taking advantage of the human perceptual structure through the use of animation and visualization to stimulate the cognitive identification of patterns in information. Investigating the presentation of information through a visual medium or by manipulating information through a visual-based application can be approached through the analysis of viewer preferences, learning perspectives, or viewer orientation. Examples of this include the animation synthesis research by Ong & Hilton in 2006 and the three-dimensional visualization application research by Fellner in 2007.

Jeremy Ernst (jeremy_ernst@ncsu.edu) is an Assistant Professor in Technology, Engineering, and Design Education and Aaron Clark (aaron_clark@ncsu.edu) is an Associate Professor in Graphic Communication at North Carolina State University, Raleigh

The study of technology-based content and the application of conceptual modeling, data-driven visualizations, physical modeling, and presentations simultaneously promote technological, technical, and visual literacy (Clark & Ernst, 2006). Technological and visual literacy maintain a significant role in successful knowledge and skill development in technology-based career paths. Modeling, visualizing, and presentations reinforce the concepts of communication technology. This strengthens individual technological and scientific knowledge and ability while providing opportunities to firmly grasp the principles behind the technologies (Newhagen, 1996).

Written, spoken, and mathematical languages empower people to communicate ideas and analyze and understand simple and complex information. The same is true about graphic languages. Often it is through the use of graphic tools and the application of graphical skills that complex information becomes apparent and understandable. There is a distinct advantage in conceptualizing in one's mind an artifact such as a building, a mechanical system, or the multitude of variables in a scientific experiment when they are presented verbally, mathematically, or graphically.

Background and Purpose

The National Science Foundation awarded the Visualization in Technology Education Project (NSF# ESI-0137811) initial funding to develop and pilot test 12 units of instruction. The units were selected by surveying professionals in science and technology disciplines to identify the most pressing issues associated with emerging technologies. The selected topics were then developed into units by professionals in technology education, science education, graphics education, and psychology. The units utilize scientific visualization as the means of conveying technological and scientific concepts to students.

The Visualization in Technology Education units are based on benchmarks identified in the Standards for Technological Literacy (International Technology Education Association, 2000) and highlight National Science Education Standards (National Science Teachers Association, 1996) when appropriate. The units are specifically designed to provide technological experiences to students through the use and creation of visualizations. Each unit was designed to address technological competencies through learning, researching, and creating visualizations. A design brief format was developed for each unit of study to better facilitate this form of learning. Professionals in visualization assisted in the development of each topic's content so that not only the Standards for Technological Literacy are addressed, but the learner is led into the development and creation of visual-based representations.

The instructional units include agricultural and related biotechnologies, medical technologies, transportation technologies, information and communication technologies, and the principles of visualization skills (refer to Table 1 for the instructional units).

Table 1
Visualization in technology education units

Unit 1: Communications Technology: Introduction to Visualization
Design process for graphic communication of technical and scientific information. Includes the inadvertent and purposeful graphical misrepresentation of information. Standard: Information and Communication Technologies of the Designed World.
Unit 2: Medical Technology: Imaging
History and societal ramifications of medical technology. Standards: Medical and Information and Communication Technologies of the Designed World.
Unit 3: Biotechnology: Polymerase Chain Reaction
History, social, and ethical implications of biotechnology and its application, especially relative to the polymerase chain reaction (PCR). Standard: Agricultural and Related Biotechnologies of the Designed World. .
Unit 4: Transportation Technology: Visualizing Rocketry
Basic aeronautical principles, the use of chemical reactions for rocket transport, and the application of Newtonian physics and mathematical tools in rocket design. Standards: Transportation Technologies and Information and Communication Technologies of the Designed World
Unit 5: Communications Technology – 3D Modeling and Animation
3D computer animation tools and use of object oriented graphics software to represent different types of pump technologies. Includes the mathematical and geometric basis for 3D modeling and animation. Standard: Information and Communication Technologies of the Designed World.
Unit 6: Energy and Power Technology
Forms of energy, law of conservation of energy, and the role that technological tools play in the transformation of energy from non-useful forms to useful forms. Includes renewable and nonrenewable energy resources. Standard: Energy and Power Technologies of the Designed World.
Unit 7: Bioprocessing
The use of bioprocessing technologies to produce the variety of products by the industrial, pharmaceutical, food, and environmental sectors. Standard: Agricultural and Related Biotechnologies of the Designed World.
Unit 8: Prosthetics
History, design, and construction related to prosthetics. Includes the societal implications of providing support for persons with disabilities.Standard: Medical Technologies of the Designed World.
Unit 9: Weather
Remote imaging technologies and data collection related to weather. Includes image measurement, sequencing, comparison, and enhancement as well as weather tracking. Hurricane Katrina and Rita are used as references.
Unit 10: Careers
Research and decision-making related to careers from a local to a global perspective. Includes working conditions, salary, educational requirements, and geographical considerations.

Table 1 (continued)
Visualization in technology education units

Unit 11: Nanotechnology
Nanotechnology with an emphasis on its multidisciplinary nature with the inclusion of fields such as chemistry, physics, biology, materials science, and engineering.
Unit 12: Biometrics
Biometric tools that include a wide range of biosecurity technologies that precisely confirm an individual's identity using physical or behavioral characteristics.

The twelve units are on six CDs (three instructor CDs and three student CDs). Each Visualization in Technology Education Instructor CD contains an overview of the unit materials, unit projects, teacher resources, and unit PowerPoint presentations. Areas of study within Visualization in Technology Education involve the use of science to create and develop visualizations to better explain a given topic. Numerous visualization techniques are used to effectively teach subject matter such as 2D illustrations composed through simple sketching software, 3D models generated with dynamic animation packages, and 2D graphing applications utilizing spreadsheets.

The purpose of these materials is twofold. The first is to focus on the skills, concepts, and principles inherent within the Standards for Technological Literacy – the de facto national standards for technology education in the United States. The second is to help students become better visual communicators and problem solvers.

Three overarching questions were addressed by both the original Visualization in Technology Education study, as well as the supplemental study. First, is the technological knowledge of students enhanced through the use of standards-based instructional materials? Second, can a student's preferred learning style serve as an indicator of spatial acuity? Third, do digital computing project-based activities improve technological competency? These questions resulted in thirteen hypotheses based on the goals approved by the National Science Foundation. The 13 hypotheses are presented in Table 2.

By the creation of visualizations, students learn to use different types of computer applications that will be useful as they select a direction for their future study. Also, areas within computational science, technology, and communication will be enhanced as they learn to communicate to a variety of audiences (Clark & Matthews, 2000). Students are not only developing visualization skills, but at the same time learning useful information and gaining skill sets that will make them better communicators and presenters. The overall design of Visualization in Technology Education materials is to link technology literacy standards to areas within scientific, visual, and spatial literacy through the understanding and development of knowledge and skills in scientific and technical visualization.

The outcomes, or final models, for activities within each unit can be conceptual or data-driven forms of communication. Conceptual modeling and data-driven modeling are the two fundamental types of visualizations that students create through the Visualization in Technology Education activities.

Table 2
Hypotheses for supplemental field-test year of the project

$H_0 1$:	There are no differences in student pretest competency and student posttest competency in the 12 Visualization in Technology Education instructional units.
$H_0 2$:	There are no differences in student spatial visualization pretest acuity and student spatial visualization posttest acuity.
$H_0 3$:	There are no differences in female student spatial visualization pretest acuity and female student spatial visualization posttest acuity.
$H_0 4$:	There are no differences in male student spatial visualization pretest acuity and male student spatial visualization posttest acuity.
$H_0 5$:	There are no differences in rural area student spatial visualization pretest acuity and rural area student spatial visualization posttest acuity.
$H_0 6$:	There are no differences in suburban area student spatial visualization pretest acuity and suburban area student spatial visualization posttest acuity.
$H_0 7$:	There are no differences in urban area student spatial visualization pretest acuity and urban area student spatial visualization posttest acuity.
$H_0 8$:	There are no differences in middle school student participants' spatial visualization pretest acuity and middle school student participants' spatial visualization posttest acuity.
$H_0 9$:	There are no differences in high school student participants' spatial visualization pretest acuity and high school student participants' spatial visualization posttest acuity.
$H_0 10$:	There are no differences in spatial visualization pretest acuity for student participants with predominant preferred visual learning styles and spatial visualization posttest acuity for student participants with predominant preferred visual learning styles.
$H_0 11$:	There are no differences in spatial visualization pretest acuity for student participants with predominant preferred aural learning styles and spatial visualization posttest acuity for student participants with predominant preferred aural learning styles.
$H_0 12$:	There are no differences in spatial visualization pretest acuity for student participants with predominant preferred reading/writing learning styles and spatial visualization posttest acuity for student participants with predominant preferred reading/writing learning styles.
$H_0 13$:	There are no differences in spatial visualization pretest acuity for student participants with predominant preferred kinesthetic learning styles and spatial visualization posttest acuity for student participants with predominant preferred kinesthetic learning styles.

Conceptual models are created when an idea or process cannot be easily explained with words or mathematics but can be explained effectively using a picture or animation. Depending on the complexity of the topic, these models can be either two-dimensional or three-dimensional. Also, conceptual models are either static, such as a picture, or dynamic, as with an animation. Data-driven models summarize data sets to convey a large set of numerical information into a small concise way that is easily understood. Charts and graphs are typically used to show this type of information. Data-driven models can also be either two-dimensional or three-dimensional, based upon the number of independent variables to be shown. Regardless of whether the visualization is conceptual or data-driven, students need to know the best practices to show the information they are given in the Visualization in Technology Education activity and then develop a model and present it to the class using the appropriate software tools.

Modeling and visualization abilities are driven by spatial acuity (Sorby, 2006). Receptiveness to modeling and visualizing content presentations is largely dictated by learning experiences. This being the case, an investigation was needed that went beyond the assessment of technological content area competency gains through the use of the Visualization in Technology Education instructional materials. The evaluation of spatial acuity and learning preferences for student participants are important variables in visualization-based investigations (Sorby, 2000; Harris, Sadowski, & Birchman, 2006). The study of these variables allowed the researchers to investigate the spatial skill development of the students who used the Visualization in Technology Education materials.

Methodology

The primary purpose of this study was to examine the effectiveness of the visualization-based curriculum materials in teaching technology concepts as specified in the research questions stated earlier. Technology educators were selected from across the United States to pilot test the Visualization in Technology Education materials. They were solicited through the Southern Regional Education Board and the "High Schools That Work" program.

To assist in the evaluation of the materials, workshops were conducted before each pilot year to familiarize the participants with the materials and piloting procedures. In the fall and early spring of each pilot school year, multiple-choice tests were given before and after each unit to measure the extent to which students learned the content of the unit. The tests were developed and administered by the Research Triangle Institute, an external agency that conducts a wide range of research, including educational research. This institution also served as the evaluator for the project.

During the pilot testing some students participated in more than one Visualization in Technology Education unit. During the 2002–2003 school year, six Visualization in Technology Education teachers pilot tested the first four units. During the 2003–2004 school year, seven teachers were asked to pilot test the second four Visualization in Technology Education units. During the 2004–2005 school year, the seven pilot teachers tested all or a selected number of the last four units.

Through analysis of the data collected in the pilot study on units 1 to 12, it was found that students who participated in the Visualization in Technology Education units significantly increased their knowledge in the areas of technology covered by the units. In addition, teachers rated all of the twelve units as effective in enhancing students' understanding of the intended learning goals and objectives. This rating was consistent with the results of the student test scores.

Supplemental Research Study

In 2005 the Visualization in Technology Education project was granted an additional year (2005-2006) to field-test the units while collecting data. To further disseminate the Visualization in Technology Education materials, a workshop was conducted in July 2005, randomly selecting 14 volunteers from across the United States to test the materials in their final, published form.

Assessments

In the fall and early spring of the 2005-2006 school year, three assessments were administered at each of the 14 field test sites. One assessment consisted of the pre-assessments and post assessments for each unit. These instruments included 20 multiple choice questions and were intended to measure student knowledge gained after the completion of the unit and were directly correlated to the Standards for Technological Literacy (ITEA, 2000). As mentioned earlier, the instruments were developed by the Research Triangle Institute.

The second assessment was the Mental Rotation Test from the Purdue Spatial Visualization Test. This instrument assesses the ability of students to visualize three-dimensional objects after they have been rotated. It presents a three-dimensional drawing of an object. Five possible drawings of that object are presented, one of which accurately shows the object after is has been rotated to a new position. This test was used to determine if students improved their visualization capabilities as a result of using the Visualization in Technology Education instructional materials.

The third assessment was the VARK Questionnaire to measure the dominant learning style of a subject with respect to four dimensions: **V**isual, **A**ural, **R**ead/write, or **K**inesthetic. The primary reason for administering the VARK Questionnaire was to determine learning style preferences relative to spatial visualization, orientation, and acuity. The VARK Questionnaire is composed of 16 questions that require the student to choose the statement that best explains their learning style preference (Fleming, 2006). If more than one choice matches their perception, then more than one statement can be selected.

Fleming (1995) identified visual learners, coded with "V" by the VARK Questionnaire, as those who prefer information to appear in the form of graphs, charts, and flow diagrams. The most familiar method for information transfer in our society is speech. Speech is recognized through hearing and is consequently coded as aural (A) by the VARK questionnaire. Respondents with a preference for accessing information from written words would be coded as Read/writers

(R) since they prefer reading and writing for information acquisition. Those who prefer using all their senses (touch, hearing, smell, taste, and sight) are considered kinesthetic (K) learners. They prefer tangible, multi-sensory experiences in their learning.

In both the original research study and the supplemental research study, comparison groups were not utilized. Through the use of comparison groups, the researchers would have been able to identify more distinctive academic performance increases over non-visualization based strategies. However, student academic knowledge gains were uncovered in the single treatment group that included the pre/post testing approach.

Demographics

The field test population across the 14 sites included 879 students. No teacher or student participants that took part in the pilot test were permitted to participate in the field test study. The student participants ranged from grades six

Table 3
Student Participant Demographics (n = 879)

	n	***%***
Gender		
Male	534	60.75
Female	322	36.63
Missing	23	2.62
Grade		
6th	84	9.56
7th	228	25.94
8th	330	37.54
9th	99	11.26
10th	34	3.87
11th	28	3.19
12th	27	3.07
Missing	49	5.57
Ethnicity		
Asian	47	5.39
Black	214	24.36
Latino	19	2.11
Native American	8	0.94
White	583	66.28
Other	8	0.94
Geography		
Rural	297	33.79
Suburban	203	23.09
Urban	379	43.12

to 12. The field test sample was predominately male (534 = 61%). The ethnic distribution was representative as was the geographical distribution among rural, suburban, and urban areas.

Data Analysis

Collectively, student participants experienced statistically significant technological content knowledge gains in10 of the 12 Visualization in Technology Education instructional units as they relate to understanding the Standards for Technological Literacy-based content (Table 4). In Unit 4, Transportation Rocketry, and Unit 5, 3D Modeling, students experienced a notable improvement in technological content knowledge but the difference was not statistically significant at the $\alpha = 0.05$ level.

Table 4
t-test for unit content knowledge

Unit	***N***	***M***	***SD***	***df***	***t***	***p***
1. Communications Technology: Introduction to Visualization	88					
Pretest		3.98	2.28	84	7.84	<.0001
Posttest		6.26	2.13			
2. Medical Technology: Imaging	88					
Pretest		6.72	2.22	83	5.61	<.0001
Posttest		9.58	4.00			
3. Biotechnology: The PCR	49					
Pretest		5.73	2.21	45	3.18	0.0027
Posttest		8.00	5.17			
4. Transportation Technology: Visualizing Rocketry	115					
Pretest		7.84	3.82	106	1.04	0.3028
Posttest		8.17	4.45			
5. Communications Technology: Introduction to 3D Modeling and Animation	35					
Pretest		4.70	1.79	28	1.05	0.3046
Posttest		5.34	1.23			

Table 4 (continued)
t-test for unit content knowledge

Unit	*N*	*M*	*SD*	*df*	*t*	*p*
6. Energy & Power Technology	93					
Pretest		7.48	3.31	84	7.01	<.0001
Posttest		14.01	8.06			
7. Bioprocessing	35					
Pretest		5.86	2.68	34	7.8	<.0001
Posttest		13.51	5.07			
8. Prosthetics	98					
Pretest		7.25	3.63	86	6.43	<.0001
Posttest		10.36	3.90			
9. Weather	128					
Pretest		3.43	1.71	113	2.39	0.0187
Posttest		3.93	2.21			
10. Nanotechnology	23					
Pretest		5.35	1.94	22	5.54	<.0001
Posttest		8.91	2.98			
11. Biometrics	47					
Pretest		5.38	1.95	42	4.6	<.0001
Posttest		7.22	2.00			
12. Careers & Technology	75					
Pretest		7.00	3.25	68	12.8	<.0001
Posttest		11.12	2.61			

Student participants in the Visualization in Technology Education showed spatial visualization enhancement as measured by the Purdue Spatial Visualization Test. However, the improvement was not found statistically significant at the $\alpha = 0.05$ level (Table 5).

Table 5
t-test for Overall Purdue Spatial Visualization Test (n = 572)

	M	*SD*	*df*	*t*	*p*
Pretest	12.85	6.54	512	1.94	0.053
Posttest	13.56	6.87			

Female participants in the Visualization in Technology Education program showed a high degree of spatial visualization enhancement as measured by the Purdue Spatial Visualization assessment. The improvement was found to be statistically significant at the $\alpha = 0.05$ level (Table 6). Male participants showed minimal spatial visualization enhancement measured by the Purdue Spatial Visualization assessment. The improvement was found not to be statistically significant at the α = 0.05 level (Table 6). However, males achieved higher initially on the Purdue Spatial Visualization assessment than females, suggesting a possible ceiling effect.

Table 6
t-test for overall Purdue Spatial Visualization Test by gender

Gender	*N*	*M*	*SD*	*df*	*t*	*p*
Male	362					
Pretest		13.38	6.85	329	0.07	0.944
Posttest		14.31	7.33			
Female	210					
Pretest		11.16	5.59	182	3.39	<0.001
Posttest		12.28	5.79			

Participants from rural, suburban, and urban schools in the Visualization in Technology Education program showed spatial visualization enhancement as measured by the Purdue Spatial Visualization assessment. However, the improvement was found not to be statistically significant at the α = 0.05 level (Table 7).

Table 7
t-test for Purdue Spatial Visualization Test based on geography

Location	*N*	*M*	*SD*	*df*	*t*	*p*
Rural	158					
Pretest		13.82	5.72	153	1.83	0.068
Posttest		15.00	5.93			
Suburban	118					
Pretest		17.74	7.59	102	1.5	0.137
Posttest		18.67	6.73			
Urban	296					
Pretest		12.99	6.32	255	0.49	0.623
Posttest		14.44	6.84			

Middle and high school participants in the Visualization in Technology Education program showed spatial visualization enhancement as measured by the Purdue Spatial Visualization assessment. However, the improvement was found not to be statistically significant at the α = 0.05 level (Table 8).

There was no statistically significant difference among Visualization in Technology Education participants relative to their preferred learning style and gains on Purdue Spatial Visualization assessment (Table 9). Eighty-eight student participants did not complete the VARK Questionnaire.

Table 8
t-test for Purdue Spatial Visualization Test

Level	*n*	*M*	*SD*	*df*	*t*	*p*
Middle School	410					
Pretest		11.35	5.58	375	1.19	0.233
Posttest		12.00	6.31			
High School	162					
Pretest		17.51	7.11	136	1.78	0.076
Posttest		17.51	6.67			

Table 9
t-test between VARK preferred learning styles and Purdue Spatial Visualization (n=572)

Learning Styles	*M*	*SD*	*df*	*t*	*p*
Visual					
Pretest	0.71	4.50	149	0.23	0.819
Posttest	0.90	5.00			
Aural					
Pretest	0.97	3.51	82	-0.19	0.850
Posttest	0.80	4.05			
Read/Write					
Pretest	0.37	3.70	94	1.14	0.257
Posttest	1.36	4.22			
Kinesthetic					
Pretest	0.80	4.33	95	0.39	0.696
Posttest	1.20	4.94			

Conclusions and Recommendations

This study contributes to the findings established by previous Visualization in Technology Education research that individual technological and scientific knowledge and abilities can be strengthened through the study and creation of visualizations (Clark & Ernst, 2006; Ernst & Clark, 2007). From the analyses of the Visualization in Technology Education field test data, it was found that students who participated in the program significantly increased their knowledge in the areas of technology in 10 of the 12 units. In Unit 4, Transportation Rocketry, and Unit 5, 3D Modeling, students showed some gain in technological content knowledge but the gain was not statistically significant. An observational follow-up on these two units revealed that some teacher participants reverted to traditional methods instead of those prescribed by the project. Both Rocketry and 3D modeling have a relatively long history in technology education as a means of conveying important concepts and principles. This content can be deepened and strengthened through virtual means with activities that apply mathematical (geometric), aeronautical, and physics principles. However, this can be accomplished only if the teacher follows the prescribed instructional and laboratory practices. With the exception of these two units, this study supports the conclusions of previous research that showed student retention of information is enhanced through scientific visualization (see Bomphrey, 2006; Payri, Pastor, Garcia, &Pastor, 2007).

Females showed higher gains than males on the Purdue Spatial Visualization Test and thus showed higher visual acuity gains. However, male participants had higher initial spatial abilities than females. There are a number of reasons why this occurred such as different opportunities to manipulate 3D objects and preferences for certain types of activities. However, none was measured by this study.

There was a continuous increase in initial spatial ability with increasing grade level. This was expected, of course, due simply to increasing maturity and increased opportunity to manipulate 3D objects. Based on the researchers' informal observations, an increase in the inclusion of virtual-based activities would have developed the spatial acuity of the participants even more. Some of the instructional units relied on physical rather than virtual modeling activities. This was done to appeal to a larger variety of learner style preferences. However, there is evidence by Sorby (2000) that virtual object manipulation is most effective in enhancing spatial acuity.

The preferred learning styles of the participants were rather evenly distributed by gender and grade level. Those who had Reading/writing as their preferred learning style showed slightly greater gains in spatial visualization than those with Visual, Aural, or Kinesthetic learning styles.

The researchers found indirect relationships between technological literacy, visualization, and learning styles. Learning styles and their relationship to visual experiences is complex. The findings from this study did not find a relationship between learning style and the utilization of visualizations. Thus, the study reinforced the notion that many students prefer multi-modal forms of learning, even if they have a dominant learning style preference. More research is needed to find better ways to link students learning styles to the type of materials and activities typically found in technology education courses.

The abilities to problem-solve and think critically can be augmented in technology education curricula through the design and the creation of visualizations. This study showed that the use of digital media, combined with standards-based content, produces materials that can meet the Standards for Technological Literacy. The results of this study support further use of this new and innovative form of instruction.

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A Theoretical Framework to Guide the Re-Engineering of Technology Education

Todd Kelley and Nadia Kellam

Introduction

Before leaders in technology education are able to identify a theoretical framework upon which a curriculum is to stand, they must first grapple with two opposing views of the purpose of technology education – education for all learners or career/technical education. Dakers (2006) identifies two opposing philosophies that can serve as a framework for technology education, both inspired by ancient Greece, with the works of Descartes and the birth of positivism. Later reappearing in Pascal's writings of the mathematical mind, and finally with Rousseau in the mid 1700s, the theoretical arguments of academic verses vocational were established in education, and thus concluded that the overall purpose of education was to make a man (human being) or a citizen. This dichotomy of views is referenced here to make explicit the underpinnings of a theoretical framework for technology education. The position that the authors take in this dichotomy of views is one that embraces the best of both views by teaching technology education to all students to foster technological literacy while at the same time addressing the needs of a workforce seeking to compete in a global economy. This rationale will be presented throughout the article.

Theoretical Perspectives of Technology Education

Early in the 1990s, in the midst of the name change from industrial arts to technology education, the *Journal of Technology Education* (JTE) published a special theme issue dedicated to examining the state of technology education from different theoretical perspectives (Herschbach, 1992). Herschbach (1992) explains that although curriculum development is not an exact science, there are five basic curriculum patterns generally recognized by curriculum theorists. He identified the five patterns as academic rationalist (separate subjects), technical/utilitarian (competencies), intellectual processes, personal relevance, and social reconstruction.

Todd Kelley (trkelley@purdue.edu) is a faculty member in the Department of Industrial Technology at Purdue University, West Lafayette, Indiana and Nadia Kellam (nkellam@engr.uga.edu) is a faculty member in the Department of Agricultural and Biological Engineering at the University of Georgia, Athens.

The special 1992 issue of JTE featured five authors from the field of technology education (Erekson, Herschbach, Johnson, Petrina, and Zuga) with each author discussing one of the five theoretical frameworks as they relate to technology education. Today, with the field of technology education on the verge of a new shift in focus, it is appropriate to consider a new theoretical perspective for technology education based upon the needs of today's learners and upon new knowledge of teaching and learning obtained through recent research.

The Archway of Meaningful Learning: A Proposed Theoretical Framework

The graphic in Figure 1 illustrates an archway to meaningful learning in technology education. The archway begins with a constructivist approach to learning through a pragmatist or experimental over-arching philosophy as the theoretical foundation upon which all the other learning theories and approaches to learning rest upon. Contextual learning/problem-based instruction and project-based instruction create columns of support for engineering design and systems thinking to provide meaningful learning through a real-world context. Both engineering design and systems thinking become the "drivers" of the learning experience. Systems thinking is above project-based instruction because systems thinking is required for solving open-ended and ill-structured problems that society faces today and such problems are prevalent in engineering design projects. At the top of this archway of meaningful learning is *student learning,* forming the keystone of the arch, at the heart of why we need to teach from a

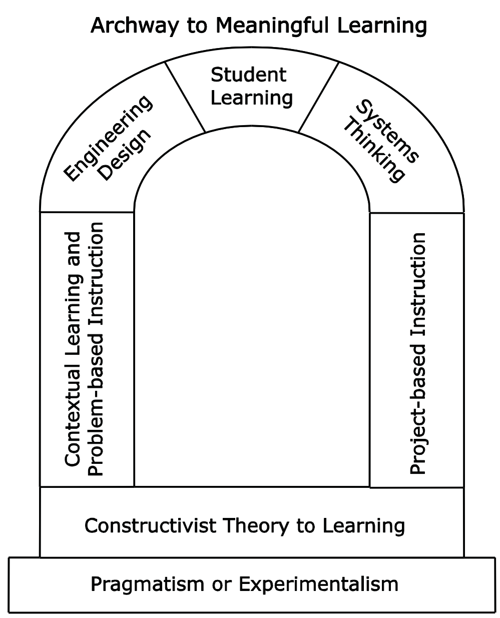

Figure 1. The Archway to Meaningful Learning in Technology Education.

constructivist approach. Student learning is supported by all other "building blocks." Throughout the rest of this article, the authors will present their rationale for why technology education should adopt this theoretical framework and describe the benefits of adopting this approach to technology education.

Pragmatism or Experimentalism

The conceptual underpinning of the proposed philosophy of technology education is founded on the ideas supported by the works of Woodward (1894), Dewey (1916), and Warner, Gray, Gekbracht, Gilbert, Lisack, Kleintjes, et al. (1947), each of whom proposed that technology education is for all learners. That is, they believed that technology education should equip the learner with necessary knowledge, skills, and abilities in the context of technology, and to live, function, and work in today's technological society. Furthermore, the authors embrace a pragmatist view, also known as experimentalism, which has been promoted through the progressive and reconstruction movement of the late 19th and early 20th centuries. Pragmatism supports the notion that knowledge is gained through problem solving, it places great emphasis on critical thinking and reasoning, and it seeks to solve the world's problems with an open mind (Scott & Sarkees-Wircenski, 2001). Moreover, the authors support technology education with an engineering design focus as a vehicle for fostering technological literacy while simultaneously developing the skills needed to work in a global economy. A review of some of the recent commissioned reports on preparing a workforce ready to compete in a global economy uncovers lists of necessary job skills that are also technological literacy skills (Committee on Prospering in the Global Economy of the 21st Century, 2007; National Center on Education and the Economy, 2006). Developing technological literacy goes far beyond providing vocational skills and making students "technologically savvy"; it is focused on understanding how technology has changed our world and how we live in it. Michael (2006, p. 56) adds that technology education should prepare young people to cope in a rapidly changing technological world; enable them to think and intervene creatively to improve that world; develop skills required to participate responsibly in home, school and community life (citizenship); help them become discriminating consumers and users of products; help them become autonomous, creative problem-solvers; …encourage the ability to consider critically the use, effect, and value dimensions of design and technology (technological awareness or literacy).

It is our belief that technology education, with a focus on engineering design, is as beneficial for students who want to become attorneys, physicians, accountants, business managers, clergy, and writers as it is for future engineers. One very important component of each of these occupations is that people working within them function in an environment comprised of ill-structured problems. Educators agree that problem-solving skills are critical for a successful person in today's world; however, it is important to note that ill-structured problem-solving helps to better prepare students to cope with real-world problems (Jonassen, 1997). Well-structured problems are constrained and usually have one correct answer, while ill-structured problems are not constrained and have multiple possible solution trajectories and final solutions (Jonassen, 1997). Whether a student selects the field of law, business, or medicine to study, they will encounter many ill-structured problems that are domain or context dependent (Bransford, 1994). Engineers have developed an excellent systematic approach to ill-structured problems known as the engineering design process. Engineers have an excellent record of taking a complex and often chaotic problem and using the engineering design process to consider multiple perspectives, and oftentimes break the problem down into manageable sub-problems that can be solved with a set of possible solutions. The skill of managing chaotic and ill-structured problems is useful to all occupations.

A Constructivist Approach to Engineering Design and Systems Thinking

Dewey captured the general philosophy of a constructivist view of learning when he made the statement:

> We are given to associating creative mind with persons regarded as rare and unique, like geniuses. But every individual is in his own way unique. Each one experiences life from a different angle than anybody else, and consequently has something distinctive to give others if he can turn his experiences into ideas and pass them on to others (1930, p. 3).

Jacobson and Wilensky (2006) suggest that young learners can handle complex systems thinking even at the middle school level. They suggest using a constructivist approach to learning, a philosophy of learning based upon foundational works of Dewey (1930), Piaget (1985), and Vygotsky (1998). Jacobson and Wilensky wrote: "A central tenet of the constructivist or constructionist learning approach is that a learner is actively constructing new understandings, rather than passively receiving and absorbing 'facts'" (p.22). They believe that this method of learning can increase students' understanding of complex systems as well as be more interesting, engaging, and motivating for students when assigned authentic problems studied within cooperative learning environments. Blikstein and Wilensky (2004) have conducted research in this area of systems thinking with results suggesting pedagogical approaches that involve students generating questions, hypotheses, and theories about a particular phenomenon. Students then develop experiments or create conceptual models using multi-agent or qualitative modeling software to confirm or refute their theories. Jacobson and Wilensky (2006) recommended a constructivist approach to teaching systems thinking within a team or group-learning environment.

Wankat (2002) and Becker (2002) agree that a constructivist approach is critical to improving the teaching of engineering and technology education. Reflecting on the work in *How People Learn* (Bransford, Brown, & Cocking, 2000), Wankat believes that the student, not the teacher, must be in the "driver seat" of learning. Bransford et al. described four critical perspectives of learning environments:

1. *Learner centered* – "Teachers must pay close attention to the knowledge, skills, and attitudes that learners bring into the classroom" (p. 23).
2. *Knowledge centered* – "Attention must be given to what is taught (information, subject matter), why it is taught (understanding), and what competence or mastery looks like" (p. 24).
3. *Assessment centered* – "Formative assessments – ongoing assessments designed to make students' thinking visible to both teachers and students are essential" (p. 24).
4. *Community centered* – "A community-centered approach requires the development of norms for the classroom and school, as well as connections to the outside world, that support core learning values" (p. 25).

Becker (2002) explained that a constructivist approach is inherent in the *Standards for Technological Literacy*, and that a shift from behaviorism to constructivism is critical to educate and assess today's students so that they are prepared for today's global economy. Wankat warned against the *content tyrant,* a phenomenon that takes place when the teacher lets the need to cover certain content control the teaching and learning that takes place in the classroom, something that has plagued engineering education for years (National Academy of Engineering, 2004).

Crawford (2001) suggested that there are five key strategies to actively engaging students in a constructivist approach to teaching. These five strategies are:

- *Relating* — learning in the context of one's life experiences or preexisting knowledge
- *Experiencing* —learning by doing, or through exploration, discovery, and invention
- *Applying* —learning by putting the concepts to use
- *Cooperating* – learning in the context of sharing, responding, and communicating with others
- *Transferring* – using knowledge in a new context or novel situation, one that has not been covered in class.

Contextual Learning

Notice that the constructivist teaching strategies suggested by Crawford, Wankat, Becker, and Bransford et al. emphasize the critical importance of *context* for effective teaching and learning. Contextual learning as described by Borko and Putnam (2000) is situated, distributed, and authentic. They suggest that all learning should take place, or be situated, in a specific physical and social context to acquire knowledge that is intimately associated with those settings. Borko and Putnam also advocate that for transfer of learning to occur, students must be provided with multiple similar experiences allowing an abstract mental model to form. Hanson, Burton, and Guam (2006) proposed contextual learning as a key strength for technology and engineering education programs, allowing for transfer of knowledge from core subjects. Additionally, they suggested that contextual learning is a key concept in helping technology education align with *No Child Left Behind* and providing learning opportunities for students to become prepared to work in a global economy. The context of learning is also essential in designing a solution to an ill-structured problem. Glegg (1972) suggested that the context in which a solution will be applied is not only an important design consideration but also critical to learning design. Teaching engineering design must be done within a context that is authentic. Newmann and Wehlage (1993) suggested that authentic activities have the following dimensions:

- Involve higher order thinking where students manipulate information and ideas
- Require a depth of knowledge so students apply what they know and are connected to the world in such a way that they take on personal meaning
- Require substantial communication among students
- Support achievement of all through communication and high expectations of everyone contributing to the success of the group.

Hutchinson (2002) suggested that problem-based learning is an additional field of inquiry worthy of consideration. Problem-based learning presents students with a problem situation and then they are asked to determine what is happening. "Problem solving, in this approach, involves a process of a) engagement; b) inquiry and investigation; c) performance; and d) debriefing" (Hutchinson, 2002, p. 4). Pierce and Jones (2000) suggested that the worlds of contextual learning theory and problem-based instruction can converge to produce highly conceptualized learning focused on questions and problems relating to real-world issues. Problem-based instruction is self-directed and collaborative. Authenticity of problem-based instruction is accomplished by encouraging dialogue with practicing experts and the manipulation of real data. Hutchinson also suggested formative assessments and performance of students before a panel of experts. These methods have been used successfully in engineering to develop critical thinking skills in students (Woods, Felder, Rugarcia, & Stice, 2000).

Engineering Design and Systems Thinking: The Ideal Context for Problem and Project Based Instruction

Wicklein (2006) and Daugherty (2005) endorsed engineering design as an ideal platform for addressing the standards for technological literacy (ITEA 2000/2002), while also creating an instructional model that attracts and motivates students from all academic levels. Today's workforce requires job skills that move beyond excelling in the basic core subjects (Grasso & Martinelli, 2007). A national employer survey identified desired job skills needed in today's workforce. Today's jobs "…require a portfolio of skills in addition to academic and technical skills. These include communication skills, analytical skills, problem-solving and creative thinking, interpersonal skills, the ability to negotiate and influence, and self-management (The National Center on the Educational Quality of the Workforce, 1995, p. 3). Dearing and Daugherty (2004) conducted a study to identify the core engineering-related concepts that also support a standards-based technology education curriculum by surveying 123 professionals in technology education, technology teacher education, and engineering education. The top five ranked concepts were:

1. Interpersonal skills: teamwork, group skills, attitude, and work ethic
2. Ability to communicate ideas: verbally, physically, and visually
3. Ability to work within constraints/ parameters
4. Experience in brainstorming and generating ideas
5. Product design assessment: Does a design perform its intended function? (p. 9).

The researchers surmised that these concepts, based upon the standards for technological literacy, were ranked high due to the nature of the work environment in today's society and the need for a growing diverse workforce. Hill (2006) recanted Richard Miller's words at a University of Georgia engineering conference about the need for engineers who have excellent communication skills, ability to work in teams, skills in social interactions, and good business ethics. Hill suggested that technology education is an ideal program to team up with engineering education to help young people develop these attributes. Roman (2004) considered the needs of an American workforce struggling to survive in a global economy. He wrote: "Thinking globally requires individuals who can think multi-dimensionally, integrating the technical and economic aspects of problem solving with the social, political, environmental, and safety concerns" (p. 22).

The Engineer of 2020 indicated that the engineer of the future will need to work in teams to study social issues central to engineering (National Academy of Engineering, 2004). McAlister (2003) observed that four of the twenty Technological Literacy Standards address technology and society, so teaching the social/cultural impacts of design is appropriate. We suggest using a systems thinking approach to engineering design to study technology-related social problems because this platform is an excellent way to foster technological literacy and promote the attitudes, thinking skills, and job skills listed above. However, this approach should not be applied to social engineering (Weinberg, 2003).

What is Systems Thinking and Why is it Important for Technology Education?

What is systems thinking? Jacobson and Wilensky (2006) wrote:

> Complex systems approaches, in conjunction with rapid advances in computational technologies, enable researchers to study aspects of the real world for which events and actions have multiple causes and consequences, and where order and structure coexist at many different scales of time, space, and organization (Jacobson & Wilensky, p. 12.).

Kay and Foster added: "In short, systems thinking is about synthesizing together all the relevant information we have about an object so that we have a sense of it as a whole" (Kay & Foster, 1999, p. 2). Mapping out the complex issues of a system by reducing the system down to its parts and studying the relationships within those various parts is a process that leads to a better understanding of the system. Furthermore, tensions may be identified that will likely emerge when a new approach to the system is taken. Failing to understand that these tensions exist and that the system contains these complex relationships, will likely result in a poor, inappropriate design. It is critical to understand that these relationships impact the entire system and the manipulation of one relationship, in turn, affects the entire system. Biologist Lewis Thomas wrote:

> When you are confronted by any complex social system, such as an urban center or a hamster, with things about it that you're dissatisfied with and anxious to fix, you cannot just step in and set about fixing with the hope of helping. This realization is one of the sore discouragements of our century…You cannot meddle with one part of a complex system from the outside without almost certain risk of setting off disastrous events that you hadn't counted on in other, remote parts. If you want to fix something you are first obliged to understand…the whole system (Thomas, 1974, p. 90).

Bar-Yam (2002) confirmed this dogma by making the case that the ability of science and technology to expand human performance through design is dependant upon the understanding of systems and not just the components that lie within that system.

> The insights of complex systems research and its methodologies may become pervasive in guiding what we build, how we build it, and how we use and live with it. Possibly the most visible outcome of these developments will be an improved ability of human beings aided by technology to address complex global social and environmental problems, third world development, poverty in developing countries, war and natural disasters (Bar-Yam, 2002, pp.381-382).

Frank (2005) makes a strong case for a systems approach for technology education. He pointed out that, traditionally, engineering and technology education used a bottom-up instructional approach, one that attempts to determine and deliver all the knowledge and skills needed by compartmentalizing the subjects: a separate math course, a physics course, statistics, etc. Frank proposed a different approach.

> Based on the systems thinking approach, what follows is a proposal for a way to teach technology and instill technological literacy without first teaching the details (for instance, electricity basics and linear circuits for electronics, or calculus and dynamics basics for mechanical engineering) (p. 20).

The premise to this approach is that complete systems can be studied conceptually and functionally without needing to know the details, a top-down approach. A top-down approach focuses on characteristics and functionality of the entire system and the interrelating subsystems. This approach to teaching engineering design addresses issues raised by some that suggest teaching engineering design in technology education excludes some students who have not had, or lack, an aptitude for upper level math or science. A top-down approach also provides a feasible solution to high school courses with students enrolled at various stages of learning, for example, freshmen and seniors in the same class. These issues are of great concern when suggesting that technology education with an engineering design focus is for all learners.

Frank also shares the benefits of project-based learning for technology education that include student engagement, increased motivation, and increased multidisciplinary knowledge, to name a few. Shepherd (1998) found through research that students who experienced project-based learning in a real world setting had significantly higher scores on the Cornell Critical Thinking Test compared to students in traditional instruction. Project-based learning requires students to work in teams to build a product. A misnomer in technology education is that the product created must be tangible, but Frank brings clarity to this issue. He writes:

> The product may be something tangible (such as a model/prototype, a system or a robot), a computerized product (such as software, a presentation, or a multimedia product), or a written product (such as a report, an evaluation summary or a summary of experimental findings (p.21).

A common concern in moving technology education toward engineering design is what will happen to the traditional hands-on projects that produce a physical product? We believe that the best answer to that question is to identify and understand appropriate engineering related problems to be explored in technology education. Some problems will lend themselves to tangible products while others will not. Technology educators will need to accept the idea that not every problem solving activity will or should require a physical prototype or artifact.

Why Systems Thinking and Engineering Design for Technology Education?

If technology education is to be successful in implementing a new program with an engineering design focus, it must be able to articulate the idea that learning engineering design can generate a type of thinking that can be applied to many occupations. With the application of engineering design and systems thinking, students learn how to use critical thinking skills to solve complex, ill-structured problems that are necessary to live and function in the 21st century, regardless of whether the student plans to work in a factory, on a farm, or in a courtroom. No matter what occupation students select, they will encounter many ill-structured problems, none of which can be solved with a single textbook answer. Engineering design and systems thinking provides a systematic approach to solving ill-structured problems which is a vital, universal skill that can transcend all vocations.

Conclusion

In an educational field such as technology education that has been accused of poorly communicating a clear mission (Wicklein, 2006); it appears appropriate to consider a new theoretical foundation for the field. Moreover, as new demands arise for educational programs that will equip the next generation of workers who are trained to survive and thrive in a global economy, a new philosophical framework for technology education may be needed. In this article, the authors have attempted to provide a philosophical framework for technology education that holds true to some pedagogical approaches that are at the heart of the success of technology education (contextual learning, problem-based instruction, and project-based instruction), while at the same time embracing new philosophies of learning and thinking (constructivism, engineering design, and systems thinking). The current literature is clear about the type of workers needed for today's global economy (Pink, 2005; Friedman, 2005; National Academy of Engineering, 2004; National Academy of Engineering, 2005; Woods et al., 2000). If technology educators determine that their purpose is to help prepare students to live and work in this global society, then these educators should consider carefully defining a philosophical framework upon which to build a new curriculum. The authors wish for technology educators to consider the proposed framework as a foundation for technology education as it has much promise in preparing students to function in today's technological society.

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A New Generation of Goals for Technology Education

John M. Ritz

Introduction

To develop meaningful instructional programs for technology education, goals need to be in place to direct the outcomes of curriculum development and teaching. Goals are program terminal outcomes that focus curriculum writers or teachers who structure content for learners. Goals provide direction so content can be delivered for long-term impact to students who study the subject. They go beyond everyday teaching objectives; they are directed at long-term learning and programmatic outcomes.

Goals are arrived at through at least three different sources: empirical, philosophical, or subject matter (Zais, 1976). Empirical goals are usually developed by surveying the members of society and using this analysis to determine the directions of education. Examples include improving the economic condition of a society, focusing the role of citizenship or parenthood, or establishing the cornerstones of democracy.

Philosophical sources of educational goals are derived from the thoughts of the great thinkers of the time and their beliefs of what schooling should be. For those of us who work at the university level, some academics try to influence the entire institution through the directions that they feel the general liberal arts curriculum should take. This would also include the federal government's view of setting goals that all learners need to meet.

Subject matter sources for curriculum goals are commonly used by professions to structure the importance of their subject to the greater education of all. Some criticize using the motives of subject matter specialists since they often become narrow and technical. For our profession, we must look beyond the development of engineers, industrial technologists, or craft workers. We must seek goals that take curriculum designers and teachers beyond the limits of these specific professions toward the goal of technological literacy for all. As Tyler (1950) stated, "what can a particular subject contribute to the education of young people" (p. 26).

John Ritz (jritz@odu.edu) is a Professor in the Department of STEM Education and Professional Studies, Old Dominion University, Norfolk, Virginia.

Review of Literature

Clear goals for technological literacy instruction are very important to our profession in that they provide direction for teachers to structure instruction. Goals are also important guide posts as the profession and its members to help decide if technology education should continue to have a technological literacy prospective, or if we should direct our instructional efforts on STEM (science, technology, engineering, and mathematics) education, industry certificate preparation, pre-engineering, or some other focus.

If educators only use content derived from, for example, the *Standards for Technological Literacy* (ITEA, 2000), the result might be learners who know a lot about technological content, the engineering design process, and how to perform a number of technical processes, but they would have little ability to apply this knowledge to the technological challenges and decisions they will make in everyday life.

Aims are related to goals and influence the processes of curriculum design and delivery. Unlike goals, aims are focused on very long-range outcomes and they guide the direction of schooling and society. In other words, they are the expected life outcomes from education. One set of aims that have been influential in shaping the curriculum of American schools is the *Cardinal Principles of Secondary Education* established by the Commission on the Reorganization of Secondary Education (1918). This Commission based their aims for education on the important life principles and citizenship. Thus, they would be considered as empirical sources (Zais, 1976). They were:

Health
Command of fundamental processes [basic literacy]
Worthy home membership
Vocational education
Civic education
Worthy use of leisure
Ethical character (pp. 11-16)

Whereas aims provide a broad direction for schooling, goals are more focused on the outcomes of schools. They include, for example, graduation requirements and literacy rates.

During the 1980s, U. S. politicians began observing that students in other developed nations of the world were performing better than U.S. students. These observations spawned many studies during the ensuing decade. Consequently, the U.S. was determined to be a *Nation at Risk* (NCEE, 1983). As a result, President George Bush, the 31st President, assembled the U.S. Governors in 1988 to devise a plan to improve the schooling of American youth. The plan, *America 2000*, set educational strategies to make the U.S. the best educated nation in the world (U. S. Department of Education, 1991). Ten years were set to achieve certain goals that were based on empirical sources. They included:

- All children in America will start school ready to learn.
- The high school graduation rate will increase to at least 90 percent.

- American students will leave grades four, eight, and twelve having demonstrated competency in challenging subject matter including English, mathematics, science, history, and geography; and every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, further learning, and productive employment in our modern economy.
- U.S. students will be first in the world in science and mathematics achievement.
- Every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.
- Every school in America will be free of drugs and violence and will offer a disciplined environment conducive to learning (U. S. Department of Education, 1991, p. 3).

As one might see from these statements of outcome, the American Governors used goals as tools to guide the improvement of U.S. schooling. Although not specifically mentioned, technology education fits very nicely into Goal 5 and could significantly support Goal 3.

Historically, technology education professionals have used goals to guide curriculum and instructional plans. If one were to review technology education curricula over the years, coherence would be found between what was specified by the goals and the content to be taught and the corresponding instructional activities.

As school subject leaders began to examine their effectiveness in preparing future generations after the launching of Sputnik I, so did leaders in industrial arts. The U.S. Office of Education reported in *Industrial Arts* (1961) that the predominate purpose of the field was to provide instruction based on trade and job analysis (USOE, 1961). In an attempt to redirect the profession toward general education, the USOE, in conjunction with the leaders of the profession, published a document titled *Improving Industrial Art Teaching* (1962). Through this publication, a more encompassing mission for industrial arts was proposed. This document was the result of professional meetings designed to redirect the efforts of industrial arts teachers to develop instructional programs around the following four goals:

1. To develop in each student an insight and understanding of industry and its place in our culture.
2. To discover and develop talents of students in the technical fields and applied sciences.
3. To develop technical problem-solving skills related to materials and processes.
4. To develop in each student a measure of skill in the use of the common tools and machines (USOE, 1962, pp. 19-20).

During the following decades, much research and development was undertaken to improve industrial arts/technology education by embracing these broad goals. Over the years, surveys of teachers and school administrators were conducted, including benchmark studies by Schmitt and Pelley (1966), Dugger et al. (1980), and Sanders (2001). In the Schmitt and Pelley (1966) study, the priority rankings of purposes of industrial arts were to develop tool and machine skills, creative abilities, worthy use of leisure, and technical skills. Dugger et al. (1979) found that teachers believed the intentions of industrial arts teaching were to develop tool/machine skills, technical skills, creative abilities, and worthy use of leisure. Sanders (2001) found that technology education teachers sought to teach problem solving, the use of technology to solve problems, making education and occupation decisions, and the application of science and mathematics. In all three of these national studies, the researchers asked the respondents to rank order purposes.

As the profession moved from industrial arts to technology education, new lists of goals were developed. For many of the new curriculum plans that emerged, the goals that they promoted became their most important contribution. Examples include the American Industry project (1965), the Industrial Arts Curriculum Project (1968), the Maryland Plan (1973), and Technology as a Discipline (1972).

One of the significant research efforts in changing the profession to a study of technology was the *Jackson's Mill Industrial Arts Curriculum Theory* (Snyder & Hales, 1981). This panel of professionals and the document they produced outlined the content for technology education programs with a focus on the technological systems of communication, construction, manufacturing, and transportation. It also provided guidance for curriculum development by setting forth the following goals (Snyder & Hales, 1981, p. 42):

- To understand and appreciate the evolution and relationships of society and technical means;
- To establish beliefs and values based upon the impact of technology and how it alters environments;
- To develop attitudes and abilities in the proper use of tools, techniques and resources of technical and industrial systems;
- To develop creative solutions to present and future societal problems using technical means;
- To explore and develop human potentials related to responsible work, leisure, and citizenship roles in a technological society.

The authors of the Jackson's Mill work felt that the history of technology, impacts of technology, abilities to use technology, problem solving, and work and citizenship were important outcomes for all technology education students.

Following this work, the International Technology Education Association developed *Technology Education: A Perspective on Implementation* (1985) to help the profession understand why it was changing its content-base from industry to technology and cited examples of how such programs might be implemented. In this work, the authors proposed goals for technology education for the elementary, middle, and high school levels. They included:

- Know and appreciate the importance of technology
- Apply tools, materials, processes, and technical concepts safely and efficiently
- Uncover and develop individual talents
- Apply problem-solving techniques
- Apply other school subjects
- Apply creative abilities
- Deal with forces that influence the future
- Adjust to the changing environment
- Become a wise consumer
- Make informed career choices

In 1990, ITEA further refined its position for teaching technology education through *A Conceptual Framework for Technology Education* (ITEA, 1990). This document proposed the following goals for technology education:

- Utilize technology to solve problems or meet opportunities to satisfy human needs and wants.
- Recognize problems and opportunities exist that relate to and often can be addressed by technology.
- Identify, select, and use resources to create technology for human purposes.
- Identify, select, and efficiently use appropriate technological knowledge, resources, and processes to satisfy human wants and needs.
- Evaluate technological ventures according to their positive and negative, planned and unplanned, and immediate and delayed consequences.

As the profession continued to study its school subject area, it worked to establish a sound foundation for the school study of technology. In the *Rationale and Structure for Technology Education* (ITEA, 1996), ITEA listed the goals for technological literacy to include:

- Evaluate technology's capabilities, uses, and consequences on individuals, society, and the environment
- Employ the resources of technology to analyze the behavior of technological systems
- Apply design concepts to solve problems and extend human capability
- Apply scientific principles, engineering concepts, and technological systems in the solution of everyday problems
- Develop personal interests and abilities related to careers in technology

With the development of the *Standards for Technological Literacy* (ITEA, 2000), content took precedent over goals. The profession sought to identify the content that needed to be understood and/or mastered for one to become technologically literate. The research of the ITEA Standards Project (2000), headed by William E. Dugger, produced standards and benchmarks for the study of technology. ITEA chose to follow the templates for standards developed by other disciplines such as science and mathematics. By making these choices, it could be implied that the "standards movement" and its identification of specific content (standards and benchmarks) became more important than establishing and following goals in curriculum design. Correspondingly, assessment would be much easier to accomplish if the attainment of content benchmarks was measured rather than the extent to which broader goals were reached (Pellegrino, Chudowsky, & Glaser, 2001; NAE, 2002).

Content, though, has always been the primary emphasis of technology education and its predecessors. During the industrial arts era one of the goals was to "develop skill in using tools and machines" (Schmitt & Pelley, 1966). For this reason, much instruction was directed at the identification of tools and machines, their parts, and their safe and proper usage. Students were engaged in activities designed to develop skills in using equipment to perform processes using a variety of materials of industry. The goal-content dilemma relative to the *Standards for Technological Literacy* is what motivated this researcher to conduct the study reported herein.

Rationale

As the above chronology reported, the intent of technology education has changed in many ways and yet remained the same in many other ways. This study was intended to generate a new set of goals in line with the profession's current emphasis on technological literacy. Since the release of the *Standards*, there has been an ongoing curriculum development effort by the International Technology Education Association (ITEA) and its Center to Advance the Teaching of Technology and Science (CATTS). It is important for the association that the goals of the profession drive the products that it develops. The intent of this study was to regenerate goals for technological literacy to guide curriculum efforts at the elementary, middle, and high school levels. Clear program focus cannot be achieved without goals. If standards and benchmarks are used in the absence of goals, there will not be a unification of purpose and assessments will result in "teaching to the test" rather than assessing the extent to which the overarching goals were reached. This has already happened in the core academic subjects. If it were to occur in technology education, the result would be graduates who have specific knowledge about selected technologies, but who lack an understanding of the broader notion of how technology is a part of the lives of all.

Method

The purpose of this study was to generate a set of goals to guide curriculum development and instruction for technological literacy, K-12. A four round modified Delphi methodology was used among the leadership boards of the

International Technology Education Association (ITEA). The board memberships included the International Technology Education Association Board of Directors and the executive committees of the Council on Technology Teacher Education, the Council of Supervisors, the Technology Education Collegiate Association, and the Technology Education Council for Children. This constituted a population of 33 leaders from the technology education profession. Since the boards are composed of classroom teachers (elementary and secondary), pre-service teachers, local and state level supervisory personnel, and college professors, this gave representation for all educational levels of professionals. The study was approved by the ITEA Executive Board.

To begin the study, an email was sent to each board member notifying them that the study would commence. The board members were told that their participation would be voluntary. To begin data collection, a letter and white paper was sent to the board members. The letter encouraged participation and explained the process to be used to collect data, exclusively through email. The white paper was a short essay about educational goals and a description of some goals that had been used in prior eras to guide instruction in industrial arts and technology education. It also explained how the profession had moved from using goals to using standards in curriculum development. Once this information had been received by the respondents and they agreed to participate, then Round 1 of the study began. In this round, participants were asked to email the researcher two to five goals they thought were important to guide instruction for K-12 technological literacy. No suggestion was made that any of the goals from past studies should be included by the participants.

Findings

Fifty-five percent (18) of the participants responded to Round 1 and from them 32 potential goal statements were identified. As expected, some goals were stated by more that one participant. A study panel integrated these 32 statements into 21 statements by combining redundant statements in the process. See Table 1.

In Round 2 of the study, the list of 21 potential goals for K-12 technological literacy programs was sent to the 33 board members and asked them to decide if each of the goal statements should be retained or dropped from the list. They were also given the opportunity to reword or modify the goal statements. Ten members (30%) of the participants responded to Round 2 . This round resulted in a list of 12 goal statements. The statements are presented in Table 2.

In Round 3 of the study, the list of the 12 goal statements from Round 2 was sent to the original population of 33 board members. The Round 3 instrument included a five point, Likert-type scale for each of the items with 5 indicating strongly agree, 4 agree, 3 uncertain, 2 disagree, and 1 strongly disagree. This enabled the participants to indicate the extent to which they agreed with the statements.

Seventeen of the 33 members (52%) participated in Round 3 of the Delphi study process. Based on the mean values, the participants strongly agreed with five of the 12 goals. However, seven goals also had high rankings of agreement. Table 3 reports the ratings of the proposed goals for guiding curriculum development and instruction in technological literacy, K-12.

Table 1
Round 1 goal statements

Goal Statement	
1. Explain how technological systems and devices work.	12. Solve problems using technology.
2. Describe how technological systems and devices are used to assist humans.	13. Extend creative abilities using technology.
3. Explain how to troubleshoot and repair technological systems and devices.	14. Deal with the influence of technology.
4. Explain that technology can have unforeseen consequences.	15. Make informed career choices related to fields of technology.
5. Explain that technological design and innovation are tools used to improve the human condition.	16. Describe the nature of technology.
6. Know the scope of technology and how to differentiate between science, engineering, and computers.	17. Assess the interactions between technology, society, and the environment.
7. Become educated consumers of technology for personal, civil, and work usage.	18. Apply design principles that solve technological problems and extend human potential.
8. Understand that there are ethical and environmental impacts associated with the use of technology.	19. Develop abilities to live in a technological world.
9. Develop an appreciation for the role technology has played in human development.	20. Describe the designed world that has resulted from the application of technology.
10. Develop skills to use tools and designs to solve technological problems.	21. Describe the relationships between technology and other areas of knowledge.
11. Appreciate the importance of technology.	

Table 2
Round 2 goal statement results

1. Use technological systems and devices.	7. Extend creative abilities using technology.
2. Troubleshoot and repair technological systems and devices.	8. Make informed career choices related to the designed world.
3. Become educated consumers of technology for personal, professional, and societal usages.	9. Describe the nature of technology.
4. Describe social, ethical, and environmental impacts associated with the use of technology.	10. Apply design principles that solve engineering and technological problems and extend human potential.
5. Develop an appreciation for the role technology has played in the designed world.	11. Develop abilities to live in a technological world.
6. Use technology to solve problems.	12. Describe the relationship between technology and other areas of knowledge.

Table 3
Round 3 ranking of goals for technological literacy

Goal Statement	***M***	**Rank**
Become educated consumers of technology for personal, professional, and societal use.	4.76	1
Describe social, ethical, and environmental impacts associated with the use of technology.	4.70	2
Apply design principles that solve engineering and technological problems that extend human potential.	4.65	3
Use technological systems and devices.	4.64	4
Use technology to solve problems.	4.59	5
Develop abilities to live in a technological world.	4.41	6
Extend creative abilities using technology.	4.35	7
Describe relationships between technology and other areas of knowledge.	4.24	8
Develop an appreciation for the role technology plays in the designed world.	4.18	9
Troubleshoot and repair technological systems and devices.	4.00	10
Make informed career choices related to the designed world.	4.00	11
Describe the nature of technology.	3.88	12

When the initial study was planned, the researcher knew from literature and experiences with curriculum design that the fewer and more succinct goal statements are, the better it is for the learners and teachers. Today, this is especially important in assessing student progress toward attainment of the goals. For this reason, a fourth round of the modified Delphi study was planned for this analysis. In this round, the idea was to have only the Board of Directors of the International Technology Education Association participate in the study. There were 16 participants in this group. This was a representative group since each of the four affiliated councils has a seat on the board.

In Round 4 the participants were provided a rank-ordered list of the 12 goal statements from Round 3, as well as the mean values that indicated the extent of agreement. They were asked to review each goal statement and categorize it either as a "must have" or "not essential" goal. The request of the participants occurred just prior to the 2008 ITEA Conference. Fifteen of the 16 board members responded (93.75%).

Table 4
Selection of essential goals for technological literacy programs

Goal Statement	"Must Have"
Describe social, ethical, and environmental impacts associated with the use of technology.	93.3%
Become educated consumers of technology for personal, professional, and societal use.	86.7%
Apply design principles that solve engineering and technological problems.	86.7%
Use technological systems and devices.	86.7%
Use technology to solve problems.	86.7%
Describe relationships between technology and other areas of knowledge.	73.3%
Develop abilities to live in a technological world.	66.7%
Develop an appreciation for the role technology plays in the designed world.	53.3%
Troubleshoot and repair technological systems and devices.	53.3%
Make informed career choices related to the designed world.	53.3%
Describe the nature of technology.	53.3%
Extend creative abilities using technology.	33.3%

Before starting Round 4, the researcher set a criterion that 80% of the participants must indicate "must have" in order for a goal statement to remain in the final list. This process is consistent with cut-rates reported in other educational research studies such as Lewis, Green, Mitzel, Baum, and Patz (1996) and Mitzel, Lewis, Patz, and Green (2001). Using this 80% selection criterion for inclusion as a goal, five statements were identified. Table 4 reports the proportion of participants that felt that a goal statement fell into the "must have" category.

Discussion

The modified Delphi research methodology was a way to draw consensus among the elected leaders who represent the membership of the International Technology Education Association and its affiliated councils regarding the goals for the field. This resulted in five goal statements that should be used to guide curriculum and instructional development in K-12 programs in technology education and possibly at higher grade levels.

The goal ranked as most important by the professional leadership was *Describe social, ethical, and environmental impacts associated with the use of technology*. Over 93% of the leaders felt that this goal was essential. This indicates that when designing curriculum and instruction for technology education, it is important that the content taught include this social constructivist outcome. There is a significant amount of content suggested in the *Standards for Technological Literacy* (ITEA, 2000) in the area of technology and society, elementary through high school. There are many objectives and activities that could be included such as the creation and elimination of jobs, the outsourcing of work, the building of urban centers, the loss of non-English languages, and country economic status. The same holds true about the ethical impacts of technology. Ideas for content could include the use of animals to test experimental drugs or consumer products, raising the price of fossil fuels after climatic disasters such as hurricanes and floods, and ingredients in food products that can make children and animals ill such as plastic compounds in milk and dog food. Finally, the environmental impacts of technology are topics that have been viable since Earth Day was established in the early 1970s. Although technology can make for a better life, it can also destroy the earth if its impacts are not assessed.

The goal *Become educated consumers of technology for personal, professional, and societal use* was believed to be essential by the vast majority of respondents (86.7%). This goal statement indicates that students ought to become literate about the products they and society as a whole purchase and use. Consistent with this goal would be learning from what materials products are made, what materials are recyclable and how they are recycled (green technology), and what are the health and safety risks of using cell phones and text messaging. At different times in our profession, consumerism has arisen as an important part of the field. Whether one is teaching a general course on technological literacy or one that develops higher levels of technological capabilities, consumerism should be included.

A high proportion of the respondents (86.7% - same as previous goal statement) felt that students should be able to *Apply design principles that solve engineering and technological problems*. Learning to design in order to solve technological problems should be a key part of the program. The days of having students do technology activities in which they all come up with the same solution to a problem are gone. Gone as well are tracing patterns and cutting materials so that everyone in the class has the same product to take home. Design means that students develop some technical knowledge and skill, understand the impacts of their actions, and then use this knowledge and their creative abilities to solve problems through engineering and technological means. This is what some professionals intend with STEM (Science, Technology, Engineering, and Mathematics) education. This current thrust in U.S. education is to increase student knowledge and capabilities in the STEM subjects, so that they can apply it in the workforce. It is believed that with STEM experiences there will be an increase in the number of school and college completers who are better prepared to design and build innovative products to keep the U.S. economy moving forward. The profession has a long way to go in figuring out how to imbed the STEM concept into K-12 programs. It is the author's belief that STEM efforts will not be successful without the full involvement of technology education and technology education teachers. Technology educators have the unique knowledge and skill necessary to design programs that are goal-based and can show students at all levels how their science and mathematics skills can be applied in designing solutions to engineering and technological problems.

The vast majority of respondents (86.7%, like the previous two goals) felt that the ability to *Use technological systems and devices* is essential. We live in a technological society that uses both low-level tools such as screwdrivers and hammers, as well as high-level tools such as digital electronic devices, for our daily activities. Students need to learn about the basic principles and operation of these tools and related systems and it is our unique responsibility to teach students how to use them. Our classrooms and labs provide an ideal environment for students to learn these skills, particularly consumer skills, so that they can safely replace a battery in their future automobiles or sketch a diagram of a home problem that they or a service technician can help them solve. This exploration will cause some to determine the career that they may wish to pursue. They can then seek further education after graduation or as part of their life-long learning.

One must assure that our study of technology uses the tools that are school appropriate. However, we must not limit the experiences we provide to our students to the tools, machines, and systems that the school systems purchase for our laboratories. This is often the observation and criticism of professionals, including other educators, engineers, or even the comedians on late night television. They see technology education as teachers teaching students to use tools and little more. The profession needs to keep this in mind when they re-design school programs for technological literacy and base them upon the goals derived in this study.

The vast majority of respondents (87.6%, like the previous three goal statements) believe that it is essential to teach students to *Use technology to solve problems*. Not all problems are technological, but many can be solved through the use of technology. Technology requires an infrastructure such as lighting, transportation, food, etc. Students need to study real world problems in their technology programs. When designing curriculum, the enjoyable part is to have activities that reinforce the knowledge being studied with applications that are age appropriate. Sometimes themes work well while in other situations design briefs are useful. The key again to make these learning experiences successful is to engage students in activities that have multiple correct answers, not just the single answer that the teacher or curriculum designer intended. Moreover, the problems in which the students are engaged need to be changed to keep up with the technology of the times and to peak the interest of the learners.

Reflection

During the 1980s and 1990s, the Input-Process-Output Model for technological systems was very popular in curriculum design. With the goals discussed above this model is probably not as appropriate as it once was. Learners need to be more involved in developing knowledge that will change as the technology and related social issues change. The knowledge that we teach should be transferable. It should be able to be manipulated in a learner's mind and transferred to other applications.

In a technical problem-solving environment, one needs to be aware of the constraints created by society, the economy, and the systems of technology. Technological literacy programs need to study more that just the technical side, or context, of technology. Programs continue to need to develop knowledge that will enable learners to understand the socio-cultural side of technology. This context has been well reviewed in technology education literature. The *Standards for Technological Literacy* (ITEA, 2000) includes four standards that set benchmarks for K-12 students related to technology and culture. They must become an integral part of the programs we design.

Equally important is providing educational experiences to the students we serve that increase their analytical, or the problem solving, capabilities. Most people who work with technology have superior analytical skills. There is no other program in the school curriculum that can better provide these knowledge and skills than technology education. Using the goals identified in this study will lead all programs in this direction.

Conclusions

The leadership of the technology education profession has projected what they believe should be the goals to guide program development and instruction in the field. Coupling these goals with the *Standards for Technological Literacy* (ITEA, 2000) can result in the design and delivery of meaningful educational programs. The International Technology Education Association, through its Center to Advance the Teaching of Technology and Science, has continued to develop and test courses that meet these standards and at the same time integrate standards from science and mathematics. It is time for all technology education professionals to rework their curriculum and instructional practices so they are in line with the goals identified herein and the *Standards*. This will better assure that the completers of our programs are technologically literate.

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Essential Concepts of Engineering Design Curriculum in Secondary Technology Education

Robert Wicklein, Phillip Cameron Smith, Jr., and Soo Jung Kim

Introduction

Technology education is a field of study that seeks to promote technological literacy for all students. According to a recent study, in the United States, technology education is part of the state framework for 38 states, there are approximately 35,909 middle or high school technology teachers, and technology education is most frequently an elective course (Meade & Dugger, 2004). Indeed, students have an opportunity to learn about the processes and knowledge related to technology that are needed to solve problems and extend human capabilities through technology education. Wright and Lauda (1993) defined technology education as a program designed to help students "develop an understanding and competence in designing, producing, and using technological products and systems, and in assessing the appropriateness of technological actions" (p. 4).

The processes associated with technology have become key elements in technology education curriculum. A guiding influence in the development of this process-based curriculum has been the Technology for All Americans Project (Lewis, 1999; Loepp, 2004; Satchwell & Dugger, 1996; Wamsley 2003). With the publication of *Technology for All Americans: A Rationale and Structure for the Study of Technology* (ITEA, 1996), the suggested structure for the study of technology became the Universals of Technology which were identified as the processes, knowledge, and context associated with the development of technological systems:

> The processes are those actions that people undertake to create, invent, design, transform, produce, control, maintain, and use products or systems. The processes include the human activities of designing and developing technological systems; determining and controlling the behavior of technological systems; utilizing technological systems; and assessing the impacts and consequences of technological systems. (p. 16)

Robert C. Wicklein (wickone@uga.edu) is a Professor of Workforce Education at the University of Georgia, Athens. Phillip Cameron Smith, Jr. (pcameronsmith@yahoo.com) is an Engineering and Technology Education teacher at Oconee County High School in Watkinsville, Georgia. Soo Jung Kim (sjkim0624@gmail.com) is Senior Consultant in The Center for Human Resources for Samsung SDS Corporation in Seoul, South Korea.

Thus, solving problems in the context of technological systems has been identified as a key aspect of the curriculum commonly associated with technology education (Sanders, 2001). Activities that involve solving problems have been called the "philosophical nucleus" (Dugger, 1994, p.7) of technology education. Hill (1997) indicated that solving problems remains a major component of technological literacy.

Although this structure has been provided for the field, various paradigms for delivering the curriculum of technology education exist (Bensen, 1995; Devore, 1968; Hatch, 1988; Maley, 1973; Dyrenfurth, 1991; Savage & Sterry, 1990; Snyder & Hales, 1981; Wicklein & Rojewski, 1999). The actual practice of technology education in the United States has been a somewhat eclectic mix of approaches and instructional methods (Foster & Wright, 1996; Sanders, 2001). Bensen (1995) found that some programs operated with a singular concept of technology in which all the supporting parts of the curriculum were related to the whole. Others were characterized by a plural concept in which various technologies are emphasized without an effort to relate them to the larger picture of technology and its effect in our world. *The Standards for Technological Literacy* (ITEA, 2000) do not mandate a particular curricular approach (LaPorte, 2001) and technology education programs in the United States employ various approaches (Boser, Palmer, & Daugherty, 1998; Satchwell & Dugger, 1996). This fragmented focus and lack of a clear curriculum framework have been detrimental to the potential of the field and have hindered efforts aimed at achieving the stated goals of technological literacy for all students.

In recent years there has been a growing emphasis in the literature of technology education not only on the process of problem solving but also, more recently, on the integration of subject matter from various disciplines within those activities (Cotton, 2002; Engstrom, 2001; ITEA, 2003; Merrill & Comerford, 2004). This development leads to many questions for the field of technology education regarding the nature of the curriculum being offered and the proper approaches to take in administering that curriculum in technology education classrooms. As the field has begun to broaden its perspective and embrace ties with other disciplines, the topic of engineering design has begun to appear frequently in the literature (Dearing & Daugherty, 2004).

Engineering design is not simply a frequent topic in the literature of technology education; it has already begun to be included in the curriculum in some areas. Some states have adopted technology education curriculum models that are pre-engineering in nature (Lewis, 2004). *Project Lead The Way* and *Career Academies* that emphasize engineering, engineering magnet schools, and other conceptions such as the "Stony Brook" model are all examples of engineering content making its way into the middle and high school curricula (Lewis, 2004).

Conceptually, there are close ties between engineering and the field of public education known as technology education since "both engineering and technology treat solving practical problems as their philosophical nucleus"

(Dugger, 1994, p. 7). In fact, engineering has been defined as "the profession in which knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind" (Accreditation Board for Engineering & Technology, 1986, p. 1). Engineers have been described as "creative problem solvers, often imagining and designing new technologies as a means to solve problems" (Burghardt, 1999, p. 1).

However, it is evident from an examination of the literature that there are certain aspects inherent to the engineering design process which are not included in technological problem solving (Fales, Kuetemeyer, & Brusic, 1998; Wright, 2002; Hailey et al., 2005). Technology educators have indicated the need for further explanation of these differences (Gattie & Wicklein, 2007) in order to gain the expertise necessary to be able to incorporate the engineering design process in technology education classrooms. The purpose of this study was to address the question: What are the essential aspects and related academic concepts of an engineering design process in secondary technology education curriculum for the purpose of developing technological literacy?

Method

Research Design

This study relied on input from experts in the field of engineering regarding the nature of the engineering design process and how it should be taught to secondary students enrolled in Technology Education classes. The Delphi research method was used because it allows experts to have input on the topic of this study in a very efficient manner. The primary purpose of the Delphi procedure is to obtain a consensus of opinion from a group of panels (Borg & Gall, 2003; Dean & West, 1999; Salancik, Wenger and Helfer, 1971; Rojewski and Meers, 1991). Delbecq, Van de Ven, and Gustafson (1975) stated, "Delphi is a group process which utilizes written responses as opposed to bringing individuals together" (p. 83). In addition, Rojewski and Meers (1991) stated that:

> Typically, the Delphi technique is used to achieve group consensus among participants. Consensus is determined using the interquartile range refers to the middle 50% of responses for each statement (i.e., distance between first and third quartiles). (p. 11)

This study used a four round Delphi process to ascertain and prioritize the essential concepts of engineering design for the secondary technology education curriculum. Descriptive and ordinal level data collection and analysis were used to interpret panel suggestions and opinions into a collection of descriptive information for decision making. In the case of this study no prior research had been done to explain the needed curricular components of engineering design for technology education. Therefore, the Delphi technique was deemed the best research strategy to ascertain a starting knowledge base for this topic.

Population and Sample

An initial group of engineering design experts was identified through contact with Dr. Clive Dym, director of the Engineering Design Center at Harvey Mudd College, Claremont, California. Dr. Dym is an internationally recognized expert on engineering design. In April of 2006, Dr. Dym was asked to identify a panel of 10 engineering educators whom he considered to be experts in engineering design who could serve as participants in this study. Dr. Dym actually identified 12 engineering educators whom he considered to be highly qualified. These 12 individuals were contacted through email and asked to identify an additional 10 leading experts in engineering design. Ten of the original list of 12 agreed to supply names and generated a pool of 59 names. All 59 experts in the area of engineering design were invited to participate in the study with plans to narrow the pool to the 25. The number of participants desired was 25 because this number would leave room for the possible attrition of some members of the panel during the study due to circumstances beyond their control (Martino, 1983). Twenty-two (22) individuals agreed to serve on the Delphi research panel. It is important to note that each of the participants completing all rounds in this Delphi research process had a background in mechanical engineering. They were also all employed in academic settings except for one. This commonality among participants provides strength and focus for the study in that it is easy to categorize the results of this study and compare them to the results of other studies with similarly homogenous groups.

Delphi Procedure

The first Delphi probe asked the participants to provide 7-10 phrases or short answers to the four research questions: (a) What aspects of the engineering design process best equip secondary students to understand, manage, and solve technological problems?; (b) What mathematics concepts related to engineering design should secondary students use to understand, manage, and solve technological problems?; (c) What specific science principles related to engineering design should secondary students use to understand, manage, and solve technological problems?; and (d) What specific skills, techniques, and engineering tools related to engineering design should secondary students use to understand, manage, and solve technological problems? A total of 15 out of the 22 original participants completed the Round 1 survey. Two hundred and thirty-four total responses to the four research questions were recorded. Categories were created as a way to organize the responses. This was accomplished with the use of two outside reviewers who evaluated each of the responses with regard to the four research questions of the study.

The second probe of the Delphi allowed the participants to indicate their level of agreement or disagreement with each statement categorized by the reviewers based on their assessment of the Round 1 data. In addition, participants were asked if there were any additional items that they wished to add to the list of responses from Round 1. The data from Round 2 were analyzed using descriptive statistics, yielding the mean, maximum, minimum, standard deviation, and interquartile range. The most important statistic involved in a Delphi study is the median response to each item (Dalkey, 1968) because this outcome most accurately describes the overall rating of the particular item. A third probe was used to allow the experts to see how others in the sample group responded in Round 2 and to give them a chance to revise their own responses in light of the group response to the same items. A fourth probe using descriptive statistics, and the mean, maximum, minimum, standard deviation, and interquartile range were calculated to determine the degree of stability and the level of consensus among the expert panel.

Results

A four-round Delphi research process was used to elicit the responses of experts to four open-ended research questions related to engineering design in technology education.

Round 1

The survey instrument was completed by 15 of the 22 persons who had agreed to participate. A total of 234 responses were received from the 15 participants during Round 1. In order to establish content validity, these data was sent to Drs. Paul Schrueders and Tim Taylor, engineering professors at Utah State University, so that they could review the entire list of responses and categorize the data into a list of unique items. The professional literature regarding the Delphi research process recommends a panel of at least two persons to monitor this process (Turoff, 1970) of identifying the items that will form the Round 2 survey instrument.

Round 2

The list of unique responses identified by Drs. Schrueders and Taylor during the review process became the items in the Round 2 survey instrument. Participants were contacted via email and directed to access the online survey in order to indicate their level of agreement with each item on a 6-point Likert-type scale. Thirteen (13) of the original 15 participants from Round 1 completed the survey. The Round 2 survey also included space for participants to add additional items they felt should be included in order to more fully answer the four research questions.

Round 3

The Round 2 survey responses were emailed to each participant to remind each of the their previous choices. The 13 participants who completed Round 2 also completed Round 3 of the Delphi probe. The survey contained all items from Round 2 along with statistical data. The mean, maximum, minimum, standard deviation and interquartile range were calculated for each item and displayed for the participants.

In addition to the original items and corresponding statistical data, fifteen new items suggested by participants in Round 2 were added to the Round 3 survey instrument. Since these were new items, they were identified as such and had no statistical data brought forward from the previous round. As in Round 2, participants had the opportunity to add any additional items they felt would help them to answer the four research questions. Eight additional items were suggested by participants and these items were added to the Round 4 survey instrument. In addition to having the opportunity to add new survey items, participants were encouraged to provide an explanation of their answer on any particular item.

Round 4

Since the literature supports a three-round Delphi (Linstone & Murray, 1975) and also indicates that most changes will occur in early rounds of the Delphi study (Dalkey & Helmer, 1963; Dalkey, 1968), it was decided to only include items in the Round 4 survey instrument that met one or more of the following criteria: (a) Items that had a mean shift of >15% between Round 2 and Round 3 were considered to be unstable and were included in Round 4; (b) Items with an interquartile range of >1 had not reached the level of consensus desired and were included in Round 4; (c) Items on which comments were made during Round 3 were included in Round 4, along with the comments, so that all participants could see their colleagues' feedback; and (d) Items that were added in Round 3 were included in Round 4.

Fifty items fell into one or more of these categories and were included in the Round 4 survey instrument. The Round 3 survey responses were emailed to each participant to remind each of the previous choices. Twelve (12) of the 13 participants who completed the Round 3 survey accessed and completed the Round 4 survey. Each item on the survey that was brought forward from previous rounds had the associated statistical data (mean, maximum, minimum, standard deviation, and interquartile range) listed beside the question. In addition, any comments made by participants whose previous answers were outside the interquartile range (IQR) were also listed along with the survey item.

Final Results

The final results for each item appear below in Table 4. In addition to the mean, median, standard deviation, and interquartile range scores, the mean shift during the previous two rounds is reported for each item. This score indicates the degree of stability for each individual item, while the IQR indicates the level of consensus afforded the item by the participants. As described in the methods section of this study, an IQR score of < 1 is considered to be an indication that the item has reached an acceptable degree of consensus. A mean shift of < 15% is an indication that the item can be considered stable.

The literature was vague as to the appropriate method to attribute different levels of significance to the statistical scores that result from Delphi studies. Therefore, a decision was made to maintain the highest standards for the purpose of this study. It was determined that applying the most stringent criteria to the data resulting from the Delphi process would ensure that only items that were undeniably very important would be placed in the highest category and considered in the conclusions and recommendations. All other items would fall into a secondary category of lesser importance. Items considered to be very important for the purposes of this research met each of the following criteria: (a) An inter-round mean shift percentage of <15% (indicating stability); (b) A median score of 5 or 6 (indicating a strong level of agreement among participants); and (c) An IQR range of < 1 (indicating consensus).

Only the forty-eight (48) items represented in Table 1 through 4 that met the strictest requirements would be considered valid for identifying the essential aspects and related academic concepts of an engineering design process in secondary technology education curriculum. Some of the definitions of engineering design in the literature are succinct and extremely broad: "Engineering design is a systematic process by which solutions to the needs of humankind are obtained" (Eide et al., 2002, p. 79). Another one is "Engineering design is the systematic, intelligent generation and evaluation of specifications for artifacts whose form and function achieve stated objectives and satisfy specified constraints" (Dym, 1994, p. 17). Particularly for research question one in Table 1, many of the items are aspects for solving technological problems and they are not exclusive to the engineering design process. For research question number 4 in Table 4, note also that many of items pertain to general skills, techniques, and tools for solving technological problems and are not exclusive to the engineering design process.

Table 1 presents the final analysis of the Delphi research. The following items received the highest mean scores with regard to the essential features of the engineering design process for secondary students ($M \geq 5.0$): Ability to handle open-ended/ill defined problems ($M = 5.77$), Acceptance of multiple solutions to a single problem ($M = 5.77$), Systems thinking ($M = 5.69$), Oral communication ($M = 5.54$), Graphical/pictorial communication ($M = 5.54$), Understand problem identification/formulation/development of requirements lists ($M = 5.38$), Teamwork ($M = 5.31$), Conceptual design ($M = 5.23$), Critical thinking ($M = 5.23$), Ability to break down complex problems in manageable pieces ($M = 5.17$), Personal ethics ($M = 5.15$), Brainstorming and innovative concept generation ($M = 5.15$), Written communication ($M = 5.08$), Ability to integrate multiple domains of knowledge ($M = 5.08$), and Understanding of customer needs ($M = 5.00$).

In Table 2, the following survey items from the Delphi study received the highest mean scores: Multiple solutions to a single problem ($M = 5.69$), Basic Algebra ($M = 5.54$), Ability to handle open-ended/ill defined problems ($M = 5.54$), Geometry ($M = 5.46$), Spreadsheets ($M = .23$), and Trigonometry ($M = 5.00$).

According to the results of the Delphi study, the following survey items for research question three received the highest mean scores: Newton's laws: forces, reactions, velocity & acceleration ($M = 5.42$), Types of energy ($M = 5.25$), and Summation of forces/force equilibrium ($M = 5.00$) (See Table 3).

In Table 4, the following survey items received the highest mean scores: Ability to synthesize (*M* = 5.75), E-mail (*M* = 5.18), Ability to abstract (*M* = 5.17), Analogical reasoning (*M* = 5.17), and Presentation software (*M* = 5.00).

Table 1
Final Results for Research Question One Ranked by Mean Score

Research Question One: What aspects of the engineering design process best equip secondary students to understand, manage, and solve technological problems?

Item	Item #	Mean	Mean Shift (%)	Median	SD	IQR
Ability to handle open-ended/ill defined problems	15	5.77	5.65	6	0.439	6
Acceptance of multiple solutions to a single problem	17	5.77	2.75	6	0.439	6
Systems thinking	38	5.69	7.20	6	0.480	5-6
Oral communication	8	5.54	0.03	6	0.519	5-6
Graphical/pictorial communication	9	5.54	5.91	6	0.519	5-6
Understand problem identification/ formulation/development of requirements lists	1	5.38	7.97	6	1.387	5-6
Teamwork	5	5.31	1.51	5	0.630	5-6
Conceptual design	19	5.23	3.45	5	0.725	5-6
Critical thinking	35	5.23	0.01	5	0.832	5-6
Ability to break down complex problems in manageable pieces	14	5.17	3.40	5	0.718	5-6
Personal ethics	12	5.15	3.00	5	0.689	5-6
Brainstorming and innovative concept generation	18	5.15	3.00	5	0.801	5-6
Written communication	7	5.08	4.38	5	0.900	5-6
Ability to integrate multiple domains of knowledge	16	5.08	4.29	5	1.115	5-6
Understanding of customer needs	3	5.00	5.80	5	1.414	5-6

Table 2
Final Results for Research Question Two Ranked by Mean Score

Research Question Two: What mathematics concepts related to engineering design should secondary students use to understand, manage, and solve technological problems?

Item	Item #	Mean	Mean Shift (%)	Median	SD	IQR
Multiple solutions to a single problem	53	5.69	4.18	6	0.480	5-6
Basic Algebra	40	5.54	2.89	6	0.660	5-6
Ability to handle open-ended/ill defined problems	52	5.54	1.34	6	0.660	5-6
Geometry	43	5.46	5.94	6	0.776	5-6
Spreadsheets	56	5.23	1.48	5	0.927	5-6
Trigonometry	44	5.00	3.23	5	0.913	5-6

Table 3
Final Results for Research Question Three Ranked by Mean Score

Research Question Three: What specific science principles related to engineering design should secondary students use to understand, manage, and solve technological problems?

Item	Item #	Mean	Mean Shift (%)	Median	SD	IQR
Newton's laws: forces, reactions, velocity & acceleration	65	5.42	2.12	5.5	0.669	5-6
Types of energy	67	5.25	0.37	5	0.622	5-6
Summation of forces/force equilibrium	66	5.00	1.52	5	0.603	5

Table 4
Final Results for Research Question Four Ranked by Mean Score

Research Question Four: What specific skills, techniques, and engineering tools related to engineering design should secondary students use to understand, manage, and solve technological problems?

Item	Item #	Mean	Mean Shift (%)	Median	SD	IQR
Ability to synthesize	86	5.75	1.01	6	0.452	5.75-6
E-mail	82	5.18	7.17	5	0.603	5-5.5
Ability to abstract	85	5.17	1.16	5	0.718	5-6
Analogical reasoning	87	5.17	1.70	5	0.718	5-6
Presentation software	84	5.00	3.17	5	0.738	4-5

Conclusions and Recommendations

As professionals in the field of technology education grapple with incorporating engineering design in secondary level classes, several conclusions can be drawn from this research. As the process of curriculum development moves forward, professionals in the field of technology education should make use of research-based content and instructional methodology in the creation of an overall curriculum framework for understanding and implementing engineering design. The development of a curriculum that emphasizes engineering design should be prefaced by the creation of a framework which provides insight from experts in the area of engineering design and extends the current Standards-based context of curriculum development. Currently there is no overarching framework for understanding and implementing engineering design content into secondary technology education classes.

Conclusion One

With the foregoing in mind, the first conclusion to be drawn from this research is to suggest that the field of technology education could be better served if the curriculum would focus on the integration of engineering design in technology education classes. The creation and widespread acceptance of such a curriculum framework could help to bring a greater degree of solidarity to a fragmented assortment of approaches to the delivery of technology education courses currently practiced in high schools across the country. This overarching strategy of creating and implementing a solid engineering design focused curriculum framework is significant to avoid a haphazard and disjointed experience for students and also for teachers attempting to use engineering design as a curriculum organizer.

There are numerous approaches to the delivery of technology education content currently practiced in the United States, and this fragmented approach has led to confusion. It has also eroded the ability of the field to create a unified public image that would give technology education a greater degree of acceptance and influence among high school students, teachers, and parents. Technology teachers have indicated that they feel engineering design has a positive perception by the general public (Wicklein, 2004). Major stakeholders in the educational environment including administrators, teachers, parents, and students need to be able to clearly identify the goals and major activities associated with technology education. Incorporating engineering design into technology education and clearly articulating the learning outcomes, class activities, and related career opportunities could serve to improve the public perception of the field and thus alleviate many of the image problems that exist.

Conclusion Two

The second conclusion to be drawn from this study is that integrating engineering design concepts into technology education classes could provide increased rigor as students apply academic skills and knowledge to technological problems. Career, technical, and agriculture education teachers are being encouraged to provide increased rigor in the curriculum and to emphasize the application of academic content where possible. Given this context, technology education would benefit greatly from the development of an engineering design focused curriculum that features a logical progression in course content from elemental skills in introductory classes to advanced work involving the integration of concepts from mathematics and science in upper-level classes.

Engineering design is a desirable curriculum component for technology education courses for curriculum developers who are seeking to move beyond trial and error problem solving. Participants in this study were able to identify and indicate a high level of agreement with 48 items that should be included in a technology education curriculum that emphasizes engineering design. This finding gives a strong indication that engineering design can in fact be considered as a potential contributor to the field of technology education. Professionals in the field of technology education should look seriously at the benefits of infusing the curriculum with content and methodology from the field of engineering design. It is therefore incumbent upon current technology teachers to seek out ways to educate themselves about engineering design and to seek out opportunities to learn more about an engineering design focused curriculum through professional development, additional coursework, and other opportunities.

Conclusion Three

The third conclusion that can be made from the results of the Delphi study is that since survey items that addressed such as issues as generating multiple solutions to a problem (M = 5.77), solving open-ended problems (M = 5.77), the ability to synthesize (M = 5.75), systems thinking (M = 5.69), and problem identification (M = 5.38) received the highest scores overall, an engineering design focused curriculum should emphasize these broad concepts. These findings had strong correlation to the *Standards for Technological Literacy* (ITEA, 2000) and other literature in the field that emphasizes problem solving and the ability to think broadly in the context of solving technological problems. A curriculum focused on engineering design could add significantly to student learning and the knowledge base with regard to synthesizing a variety of variables (science, technology, engineering, and mathematics) to solve ill-structured problems.

An important consideration at this juncture is the current educational climate of accountability in which secondary technology education programs exist. Technology teachers should clearly communicate the goals of their curriculum and the strategies employed so that parents, administrators, and counselors are aware of the traditionally academic content that students apply in technology education classrooms while solving technological problems. This can best be done through requiring students to carefully document and communicate their design process to others. This documentation can be in the form of background research, written descriptions, hand sketches, computer-aided drawing (including 3D models), mathematical models, etc. Developing potential solutions in the planning stages may represent an improved way to enhance student understanding of design processes. Thus, teachers can display examples of student work so that stakeholders in the community become aware of the scope and nature of the technology education curriculum.

Conclusion Four

The fourth conclusion is that a variety of communication means should also be emphasized since items related to communication also received high scores. Oral, written, and graphical communication all were emphasized by the participants and were deemed an extremely important component of engineering design. This finding again has correlation to literature in the field of technology education which specifically emphasizes the necessity of good communication in a variety of forms (ITEA, 2003). A project-oriented curriculum that emphasizes teamwork and communication would be best suited for teaching the engineering design process.

Conclusion Five

The fifth conclusion from this study is that an engineering design-focused curriculum should emphasize teamwork and personal ethics. There was a high level of agreement that a secondary level technology education curriculum with an emphasis on engineering design should foster teamwork and interpersonal skills. It should also focus on the ethical responsibility of the designer to his or her fellow human beings. This finding somewhat contrasts with the typical instructional model that emphasizes the individual's responsibility to perform independently on standardized tests. This approach is congruent with the literature in the field (ITEA, 2000; ITEA, 2003) that emphasizes the importance of thinking broadly and looking for multiple points of view.

Conclusion Six

The sixth conclusion that can be drawn from this study is that the emphasis of a secondary level program should be on applying aspects of mathematical and science such as Multiple solutions (M = 5.69), Ability to handle ill defined problems (M = 5.54), Algebra (M = 5.54), Geometry (M = 5.46), Newton's Laws of Force (M = 5.42), Types of energy (M = 5.25), Spreadsheets (M = 5.23), Summation of forces (M = 5.00), and Trigonometry (M = 5.00) in ways that are directly connected to solving technology technological problems. At the outset of this study, it was thought that participants would identify many specific aspects of the various branches of mathematics and science that are especially useful in design situations. However, participants focused on general, course-related areas such as algebra, geometry, etc. rather than on detailed explanations of what specifically was most applicable. The emphasis seemed to be on structuring the curriculum so that students were required to make use of a wide range of mathematical and scientific knowledge in order to solve problems.

This wide range of subject matter encountered in the course of solving technological problems is a very beneficial development because it naturally fosters interdisciplinary instruction. Technology education teachers should seek out their colleagues in mathematics and science in order to foster collaboration on subject matter that might be unfamiliar. Collaboration with teachers from other disciplines can increase the depth of the content for students, enrich the teachers understanding of the related subject matter, and provide a more positive problem solving experience.

Conclusion Seven

The seventh conclusion from this study is that an engineering design-focused curriculum should include a hands-on component because prototyping/fabrication skills received high scores, as did product dissection. This finding fits well with typical technology education practice. In a time when the hands-on component of the curriculum has been de-emphasized in some circles, this study provided strong evidence that such learning experiences have an important place in the curriculum. Activities that emphasize modeling, fabrication, and so forth tend to be of higher interest for students and would help to create a contextual learning environment that would encourage students to truly apply academic skills and knowledge in the process of creating solutions to technological problems. Carefully structured activities can be of high interest to students while requiring them to use a variety of mental processes (Halfin,1973; Wicklein & Rojewski,1999), related academic content, and concepts from engineering design. This contextual based learning environment could be greatly beneficial to students and would follow established contextual learning models (Parnell, 1995).

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