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From the Editor

Addressing the Crisis of Identity

Once again, we face a crisis of identity. Ironically, “technology education” was chosen to eradicate our former identity crisis. The old name carried too much baggage. Most thought “technology” would capture the public’s attention and put us in good stead. Though its ambiguity was apparent from the onset, the ambiguity was thought to be more an asset than a liability. It was presumed preferable for the public to be clueless when they heard “technology education” than to think of us as industrial arts.

“Technology” *was* a good word. It had, for example, served the Science, Technology, and Society (STS) movement well. No one confused STS with Science, Computers, and Society! But that was because there *were* no computers in education when STS was developing its identity. Now, of course, “technology” *means* “computers” to all but a relatively small percentage of the population who work to understand its intended meaning.

The name change was intended to fuel a “paradigm shift” in the profession. Technological literacy for all was the underlying assumption long before it was formally adopted by the Technology for All Americans Project. But just when we were hoping the American public would begin to associate “technology” with our field, the digital revolution changed nearly everyone’s perception of the term. Thus, we’re back where we were two decades ago—ensconced in a crisis of identity.

The public *knew* what industrial arts was, but now has no concept of “technology education” and we’re not reaching them with clarification. Science education, on the other hand, has begun to educate the public about *their* technology education efforts, further confounding our dilemma. Specifically, the science education community is parading technology competitions before the public with considerable support from corporate giants. I’m not sure if they’re getting everyone’s attention, but they certainly have mine.

Though our field has sponsored technology competitions for as long as I can remember, the public has little awareness of our work in this arena. I suspect it never occurred to us to use them as corporate bait and media sound bites. But that’s exactly what science education has been so successful in doing. They’re capitalizing on the widespread appeal of technology competitions in ways we never imagined. The National Science Teachers Association (NSTA) receives more than a million dollars a year corporate support for three nationally promoted and recognized technology competitions, all of which are well publicized in the media. As a result, the public will increasingly see science education as *the* delivery vehicle for technology education.

Sam Micklus, one of technology education’s own, showed us the potential and provided the formula for big-time technology competitions. Singlehandedly, he established the Odyssey of the Mind (OM) competition (though now broader in scope, OM began solely as a technology competition). He wasted no time in landing network television air time and corporate support for the idea. He sold the OM competition all across America and later throughout the world. If my small town is indicative of others, most educators and parents of school age children know about OM competitions. In a very short span of time, Sam Micklus managed to make OM highly visible throughout America, and to some extent, throughout the world.

Similarly, science education is capitalizing on technology competitions, spreading the perception with the American public that they're leading the way in the study of technology as we know it. Technology competitions first became big business for the NSTA in 1982, with the advent of the "Duracell/NSTA Scholarship Competition." Very simply, it's a competition which challenges students to "create and build a working device powered by Duracell batteries." The competition has little to do with science; it's a technology contest. This year's scholarships total approximately $125,000, which is just the beginning of Duracell's financial commitment to this effort. This year, for the first time, the competition includes grades 7-9, in addition to 9-12. Since science is required of all children from 7-10th grades, all students 11 years of age or older potentially have an opportunity to compete for the $57,000 in scholarships offered at the 7-9 level and again at the 9-12 level. I suspect many parents are hearing about this competition through their children, thereby building the public perception of science as the purveyor of technology education. If not, they may be reading about it in the popular press (see, for example, *USA TODAY*, Sept. 22, 1993, pp. 8a-9a [full pages]).

The Duracell contest was just the beginning for NSTA. In 1993, Toshiba began sponsorship of the "Toshiba/NSTA ExploraVision Awards," perhaps the richest technology contest on the planet. ExploraVision has four levels of competition, from K-12. Students work in teams of three or four. Their charge is simply to "select a technology, or an aspect of a technology that is present in the home, school, and/or community.... explore what it does, how it works, and how, when, and why it was invented." The students project what the technology will look like in 20 years, build a prototype, and describe it with a technical report, storyboard, and videotape. ExploraVision awards approximately $350,000 in Savings Bonds and another $70,000 in travel to winners and their families *annually*. It is my understanding that, in all, Toshiba contributes as much as $1 million/year to sponsor all aspects of the competition, presumably for promotion, judging, scholarship awards, travel, and media publicity, in addition to the prizes.

The latest NSTA technology competition, sponsored by Sears, is the "Craftsman/NSTA Young Inventors Awards Program." Targeted to grades 4-6, this competition "encourages students to combine their creativity and imagination with science, technology, and mechanical ability to invent and build a tool or modify an existing tool." US Savings bonds totaling $65,000 will be awarded contest winners this year.

Each of the contests is at the heart of a public relations extravaganza. Philanthropic as these sponsors may be, it is obviously in their best interest to promote their participation in these competitions to the American public. They do this, of course, through the media, and therein lies the point. Aided by substantial corporate funding, science education is doing a terrific job of fostering the image of science as *the* delivery mechanism for technology education. Never mind all three contests are extracurricular. The *perception* these contests create is that all kids are doing technology in science class.

I think our profession should take notice of this trend. Despite having the most dynamic curriculum in all of education, technology education—as a field and school subject—remains a well-kept secret. Meanwhile, the public reads annually about three major technology competitions sponsored by the NSTA and associated with science classes across America.

Given our crisis of identity, I think we need a piece of this action. Perhaps corporate sponsored technology competitions are our best shot at gaining the visibility we so desperately need. I find it ironic that Sears is sponsoring a "science" contest that is all about the tools, materials, and processes of technology. Most science teachers do little or nothing with the tools Sears is promoting by putting the "Craftsman" name on the contest marquis. We teach about those tools every day, and the best we've managed in this regard was the "golden hammer" plaque from the Stanley Tool Company!

There are any number of technology contests that might appeal to corporate sponsors and subsequently draw attention to our field as never before. Obvious candidates for competitions include those in Manufacturing, Communication, Transportation, Computer Control, Power/Energy, and Technical Design/CAD, to name just a few. Three years ago, I promoted this idea in the ITEA Section for Communication Technology, but the Section had neither the resources nor the personnel to pursue the idea, so it never got off the ground.

So, once again, I'm wondering aloud about the potential of corporate funded contests as a possible antidote for our lingering/festering identity crisis. The influx of more than a million dollars a year from corporate sponsors for technology contests has undoubtedly bolstered the notion of science education as the delivery agent of technology education. The adage "image is everything" suggests that it behooves us to follow suit with one or more highly visible technology competitions of our own.

In the meantime, I suggest we make every effort to step up technology teacher and student participation in the Duracell, Toshiba, and Sears contests. I think we can and should incorporate the contest activities *within* the technology education curriculum. They are educationally sound and completely consistent with our current mission, goals, and best practice. ITEA has done a good job of promoting the Duracell contest in the past, but those I've polled in our field have little or no knowledge of the ExploraVision or the new Young Inventors contests.

Beyond what ITEA might do to promote technology teacher/student participation in the NSTA competitions, we should incorporate these contest guidelines and entry forms into every appropriate technology education curriculum guide, teacher education class, teacher in-service workshop, and publication of the profession. As several technology teachers have already discovered, many of the competition winners come from the same teachers and programs each year. Thus, individual technology teachers and programs could gain widespread recognition by competing successfully in these competitions, as have several already. It would bolster our image as technology educators and help to clarify our identity.

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Note: For more information on the NSTA sponsored technology competitions, see http://www.nsta.org/programs/ (look for the links to the "Student Award Programs" halfway down this page).

Articles

Exploring the Intellectual Foundation of Technology Education: From Condorcet to Dewey

Randy Chafy

Since the colonial era, Western institutionalized education increasingly has been put into the service of civilization-building by seeking to advance practical industrial needs. But education has not always had such an explicitly economic orientation. In the early Middle Ages, the purpose of education was conceived of primarily in terms of advancing spiritual well-being, Church- or State-sponsored occupations, and socially "proper" forms of knowledge. Only as European nations embarked upon colonial expansion did education begin to become associated with citizenship, nation-building, practical and secular knowledge, and the advancement of a technological civilization and private enterprise. As a result, since the eighteenth century, this second school of educational thought has become increasingly dominant in educational thought and practice.

Our contemporary understanding of science and technology education (referred to here simply as "technology education") owes much to Enlightenment-based assumptions on the nature of civilizational advancement. These assumptions are illustrated in the writings of formative educational thinkers during the eighteenth and nineteenth centuries, especially the works of Antoine-Nicholas de Condorcet and John Dewey. In examining their beliefs, I am not seeking to merely provide only an overview of educational thought but to bring into question certain fundamental assumptions embedded in the historical development of technology education. Although I acknowledge the theme of "education for citizenship" as an Enlightenment ideal that helped to generate mass education, I am more concerned with exploring the validity of using technological advancement as a benchmark of civilizational progress—an ideological belief that continues to be implicated within non-critical approaches to technology education. Put another way, I see a problematic (and limiting)

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conceptual linkage between technology, education, civilization-building, industrial growth, and human purpose.[1]

Education, Technology, and Condorcet

Throughout the Middle Ages, the Renaissance, and the Reformation, nearly all technological innovations took place on an individual craft basis; knowledge was transferred from generation to generation by apprenticeship. Significant technological advancements, such as the clock, the horizontal axle windmill, gigantic Gothic cathedrals, the printing press, and better guns and ships, were being developed outside of the universities. But these advancements, by themselves, did not cause Europeans to rethink their then-dominant understanding of human purpose in relation to spiritual perfection. Nor did the outward expansion of the market economy, which has frequently been identified as the most significant force leading to the Industrial Revolution (particularly in Marxist perspectives), cause Europeans to rethink their lofty status. The growth of the market economy is often tied closely to the growth of secular institutions, government bureaucracies, the availability of raw materials, and early trade with, later exploitation of, non-Western societies. All of these elements, it has been argued, somehow worked together to convince Europeans of the merits of industrialization; that the same development did not occur outside of Europe appears to merely reinforce this perspective. What is generally overlooked, however, is how the Europeans' growing knowledge of distant cultures helped to change their worldview of themselves and their relation to the physical world and other cultures. The Enlightenment was one result of this new orientation; another was the Industrial Revolution; and still another was a growing emphasis on the merits of technology education.

Throughout the seventeenth and eighteenth centuries, higher education in Europe and the emerging power of the United States retained a classical format. The first broadly based engineering university would not be founded until the Ecole Polytechnique was established in France in 1794. During these two centuries, however, Europeans increased their trade and colonial interactions with less technologically advanced cultures, and began to recognize their own cultural superiority in terms of technological achievements. As a result, a fundamental reorientation was beginning to take place concerning the role of technology and the purpose of education in European society.

The French Enlightenment of the eighteenth century built upon the ideas of Francis Bacon and his contemporaries. The Enlightenment was a rejection of both realism and the idea that the greatness of humankind rested in ancient knowledge. While all Enlightenment thinkers believed in certain basic principles, namely, the inherent goodness of humankind, the right to a democratic society, and that civilization must advance through technological progress to a more advanced state of being, only Jean-Jacques Rousseau and

[1]For insightful overview on the idea of progress, including the "progress system," see Almond (1982).

Antoine-Nicholas de Condorcet focused on education to any degree, and Condorcet was arguably the more thorough and influential of the two.

During mid-eighteenth century France, education was targeted at the elite, dominated by the Church, and unavailable for most of the population. The universities of France, as in most of Europe, still regarded law, medicine, and theology as the only relevant disciplines in the classical study framework; the Catholic Church and its cohort the French monarchy retained an ever-weakening hegemony in a declining and battle-weary French state. Great Britain was becoming a formidable power in Europe, and would further enhance its position by giving birth to the Industrial Revolution in the middle of the century. On the other hand, late-eighteenth century France, like Germany and the United States, was becoming increasingly "backward" by comparison, and education was beginning to be seen as a way to catch up with the British. In 1791-92, Condorcet presented a plan for a universal form of education to the French Legislative Assembly, proposing a "complete national system of secular schools to provide equal opportunity for all children, free, compulsory and universal" (Butts, 1973, p. 350). His plan was rejected at the time, but he put in place germinal ideas for mass education that later would be used in educational planning in France, Germany, and the United States.

Condorcet, like other Enlightenment thinkers, believed that there was no limit to the learning capabilities of the human mind and that progress meant the perfection of science and technology. He also believed that all "men" are products of nature, with equal rights bestowed upon them to the moral, practical, and intellectual pursuits of reason. Human progress, in his view, rested on an individual's ability to educate and refine himself in those three areas of human action. Since colonization had proven the "superiority" of Western technology, such knowledge should be spread to all through the liberating power of education.

In 1793, Condorcet wrote his great essay, *Sketch for a Historical Picture of the Progress of the Human Mind*; in it, he argued that the human mind must progress from irrationality to rationality, from superstition to reason, from pre-scientific thought to scientific enlightenment. Progress constitutes ten stages of human development, or "civilization." The first stage of civilization is the "savage" tribe, dependent on hunting, fishing, crude weapons, and simple utensils, with little government bureaucracy and only a "small number of moral ideas" (Condorcet, 1955, p. 5). Condorcet viewed the African tribe as representative of this first stage of human development, while he placed European-based societies further up the evolutionary ladder:

> Will all nations one day attain that state of civilization which the most enlightened, the freest and the least burdened by prejudices, such as the French and Anglo-Americans, have attained already? Will the vast gulf that separates these peoples from the slavery of nations under the rule of monarchs, from the barbarism of African tribes, from the ignorances of savages, little by little disappear? (Condorcet, 1955, p. 174).

For Condorcet, as a culture moves from one stage to the next, it develops more advanced technologies and bureaucratic political systems, and exhibits more personal freedoms and democratic principles.

Condorcet's tenth stage of civilization, the last and the greatest, is marked by liberty, equality, democracy and universal education for all. Of all these social developments, education is the most significant to Condorcet because it is the key to all forms of human progress: "With greater equality of education there will be greater equality in industry and so in wealth; equality in wealth necessarily leads to equality in education: and equality between nations and equality within a single nation are mutually dependent" (Condorcet, 1955, pp. 183–84). Thus, a "well directed system of education" will result in "progress" in its most basic form and "the absolute perfection of the human race" (Condorcet, 1955, p. 184). Through education, the citizen of the masses might, among other things, be taught to manage their own households, to know their rights and to exercise those rights, to be empowered in the face of those who possess authority, to overcome ignorant prejudices, to use reason to overcome superstition, and to advance the technological arts (Condorcet, 1955, pp. 182–84). Furthermore, Condorcet recognized the need for a linkage between science and the technological arts in education:

> If we turn now to the arts, whose theory depends on [the] sciences, we shall find that their progress depending as it does on that of theory, can have no other limits; that the procedures of the different arts can be perfected and simplified in the same way as the methods of the sciences; new instruments, machines and looms can add to man's strength and can improve at once the quality and the accuracy of his productions, and can diminish the time and labour that has to be expended on them. The obstacles still in the way of this progress will disappear, accidents will be foreseen and prevented, the insanitary conditions that are due either to the work itself or the climate will be eliminated (Condorcet, 1955, p. 187).

Given this faith in technology, Condorcet not surprisingly blended his understanding of education, technological progress, and reason with morality and happiness. Human reason and logic, which always work for the betterment of humankind, are responsible for keeping technological development on track. Although technological development might have limits (such as through overpopulation and the lack of food), human reason will solve those problems:

> But even if we agree that the limit will one day arrive, nothing follows from it that is in the least alarming as far as either the happiness of the human race or its indefinite perfectibility is concerned;…we can assume that by then men will know that, if they have a duty towards those not yet born, that duty is not to give them existence but to give them happiness; their aim should be to promote the general welfare of the human race or of the society in which they live or of the family to which they belong, rather than foolishly to encumber the world with useless and wretched beings (Condorcet, 1955, p. 189).

Thus, Condorcet predicted that reason would somehow progress far enough to provide the moral grounding necessary to avoiding overpopulating the world with "useless and wretched beings." Progress, reason, science, technology, and knowledge would collapse into one unified, determining force, since these are the foundations for morality.

Finally, while Condorcet condemned the ignorant prejudices of his day, what he called the "murderous contempt for men of another colour or creed," he was a firm proponent of the civilizing mission of the West. He believed that the Europeans had a duty to civilize those "savage nations who still inhabit vast tracts of land" (Condorcet, 1955, p. 175). European missionaries and their "superstitions," he predicted, would disappear, as would the existing practices of trade and colonialism for greed and profit. Instead, enlightened, newly appointed European trade representatives would be assigned to colonial outposts to act as "liberators" to the uncivilized lands of the world; teachers to educate the ignorant:

> These vast lands are inhabited partly by large tribes who need assistance from us to become civilized, who wait only to find brothers amongst the European nations to become their friends and pupils; partly by races oppressed by sacred despots or dull-witted conquerors, and who for so many centuries have cried out to be liberated; partly by tribes living in a condition of almost total savagery in a climate whose harshness repels the sweet blessings of civilization and deters those who would teach them its benefits; and finally, by conquering hordes who know no other law but force, no other profession but piracy. The progress of these two last classes of people will be slower and stormier; and perhaps it will even be that, reduced in number as they are driven back by civilized nations, they will finally disappear imperceptibly before them or merge into them (Condorcet, 1955, p. 177).

Cloaked in Condorcet's colorful prose, the preceding passage advances the notion of European "civilized" cultural superiority. And, although Condorcet condemned the "sacred despots or dull-witted conquerors" of the "oppressed" tribal cultures, he failed to acknowledge the impact of European tyrants. Ironically, the average European peasant was arguably no more liberated than the tribal cultures he criticized.

Condorcet's text was published and widely read after his death in 1794, and his ideas began to be put into practice in the early nineteenth century. But the Enlightenment emerged at a violent time in French and European history, and Condorcet himself was imprisoned as an aristocrat during the French Revolution and died shortly thereafter. Furthermore, the Catholic and Protestant Churches remained powerful stabilizing forces well beyond the Enlightenment and into the nineteenth century. Thus, although Condorcet and the other Enlightenment thinkers had only a minor immediate impact on education in Europe, they planted important seeds of change that would ultimately transform the theory and practice of European and American institutionalized education.

The Development of Technology education in the United States

The model for what can now be called "mass" education was put into place by the four Western modernizing powers of the last two centuries: Great Britain, France, Germany, and the United States. The educational systems developed by these nations helped them to realize Condorcet's vision of education, that is, mass education with a technological orientation. Although several factors played a role in the emergence of technology education—the development of the nation-state, the expansion of the market economy, the weakness of the Catholic Church, and other tangible factors—the Enlightenment represented a more crucial repositioning of civilizational advancement. Viewed in these terms, the Industrial Revolution was both a practical manifestation of this changing orientation and a foundational moment in history which helped stimulate other nations to modernize. To illustrate these assertions, I will consider some key points in the development of technology education in the United States in the post-Enlightenment era.

Although the United States is more heavily endowed with natural resources than any of its European counterparts, its ascent to economic superpower over the last century owes much to the expansion of technology education, particularly at the university level.[2] Since the American Revolution of 1776, one of the most dominant and recurrent themes in American educational philosophy has been the motif of Condorcet's concept of "education for citizenship," or education as the *right* of the people. Prominent educational historian R. Freeman Butts notes, "One of the most far-reaching results of Enlightenment theories of education was the development of education for citizenship" (Butts, 1955, p. 291). Owing much to Enlightenment thought, this theme has also been linked to other Enlightenment ideals, such as the value of natural science, progress, and technological advancement.

From its beginnings, unlike the German version of education as "enlightenment from above," educational practice in the United States exemplified the principle of "enlightenment from below"—the establishment of a universal, free, and compulsory education program under the control of public organizations. Following the American Revolution, Thomas Jefferson, a former ambassador to France sympathetic to early French Enlightenment thought, became the most formidable spokesperson for a state-supported free and universal educational system, and science was one key component of his proposed educational curriculum. As a starting point, Jefferson introduced his plan to the Virginia legislature in 1779, where, just as Condorcet would later experience in France, it failed to receive enough votes for approval. Subsequently, American education would remain in the hands of private parties, primarily the Church, until well into the nineteenth century. But Jefferson sparked a debate around the purpose of education, and his influence closely paralleled Condorcet's in Europe. By 1818, he had successfully introduced bills

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[2]Some of the most engaging histories of education in America include Smith (1990), Button (1983), Meyer (1967), Butts (1953), and the controversial Noble (1977).

that led to the founding of the University of Virginia and the reorganization of William and Mary (Heslep, 1968, p. 97).

American historian Page Smith has characterized the legacy of Jefferson as introducing an ongoing tension between two forms of “consciousness” that have shaped American educational theory and practice. The first, what he calls the “Classical Christian Consciousness,” and what the American Constitution was based on, embodies the long-standing tradition of an ordered universe governed by natural laws and laws governing human beings as defined by God Himself. This consciousness held that “the best thought and experience of the race was a precious heritage that must be preserved as a vital part of the consciousness of the new nation” (Smith, 1990, p. 35). This consciousness was evident in the long-standing dominance of classical education, with its religious underpinnings and elite nature.

Conversely, the “Secular Democratic Consciousness” embodies the values of the Enlightenment and is characterized by a “faith in limitless progress through reason and science” and “the natural goodness of man once he was free from superstition/religion” (Smith, 1990, pp. 29–30; 35). The Secular Democratic Consciousness, with Jefferson as its leading spokesperson, would eventually become the predominant consciousness, in spite of the dogma of the early classical college system in America. The new consciousness was initially aided by the pragmatic, skill-oriented teachings of Noah Webster’s spelling and grammar books in the late-eighteenth century, the introduction of *McGuffey’s Readers* in 1836, and many other similar texts that celebrated American knowledge and sought to create “traditional American values” (and I cringe at using such an expression) (Button, 1983, pp. 120–21). *McGuffey’s Readers* eventually sold 100 million copies and for over half a century served as the “principal reading matter” for rural America; young American’s were “dazzled” with such stories as “Washington and His Little Hatchet” and “Woodman Spare That Tree” (Meyer, 1967, p. 200). The values espoused by the *Readers* were as much Victorian as American, but they served to inspire “patriotic and moral values” and “loudly proclaimed the glories of resourcefulness and the sadness of indolence” (Butts & Cremin, 1953, p. 274). Yet, the Classical Christian Consciousness remained dominant in education throughout the nineteenth century, and distinct core curriculums, such as programs in engineering and science, and professional majors did not commonly appear until near the turn of the twentieth century. Smith notes that the debate between these two schools of thought “has, indeed, been continual throughout the history of the republic and goes on scarcely diminished to the this day” (Smith, 1990, p. 35).

Responding to Jeffersonian and pragmatic ideals, by the middle of the nineteenth century, a rising chorus of voices began calling for a public education system, voices including Horace Mann, James G. Carter, Henry Barnard, Calvin Stowe, Caleb Mills, John D. Pierce, Ninian Edwards, Calvin Wiley, and Charles F. Mercer. Foremost among these men was Horace Mann, who was one of the first to put into place a free state educational system for primary schools. Writing in 1847, Mann advanced the “natural rights” theme of Condorcet and argued that education was the “*absolute right* of every human being that comes into the world” (Mann, 1971, p. 35). Mann held that institutionalized, government-supported free education should be the responsibility of each successive generation (Mann, 1971, p. 46). Mann's ideas were influential in moving education away from the lingering classical education for the elites to public education for the masses.

Although aspects of Enlightenment science—including the ideas of Descartes, Newton, Copernicus, Galileo, and Kepler—crept into the curriculums of traditional institutions such as Harvard beginning in the early eighteenth century, technological university-level institutions did not appear for another 100 years. Finally, in the early nineteenth century, Rensselaer Polytechnic Institute and West Point were founded (Noble, 1977, pp. 22–23). At first, these schools were regarded as less prestigious than their classical counterparts. By mid-century, however, "catching up" to the European powers became an increasing concern as "the clamor of the modernizers became more insistent, claiming that economic development, industrialization, and urbanization required more and more highly trained manpower" (Butts, 1973, p. 424). Soon, other initiatives were expanding the opportunities for technological university education, and by 1860, Michigan, Maryland, and Pennsylvania had established agricultural schools (Butts, 1973, p. 424).

The voices of modernization reform grew increasingly stronger from then on, as industrialists pushed more fervently for political changes in higher education funding. By 1862, already twenty institutions could be accurately called "scientific schools," but these were insufficient to meet corporate needs. Industrialists' strongly lobbied Congress for more technically oriented schools, and their efforts resulted in the passage of the Morrill Act in 1862 (Ross, 1969, p. 44–45). The Act granted federal aid in support of state colleges in agriculture and engineering "in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life" (Ross, 1969, p. 46). To encourage the rapid building of these schools, a state was required to found a college within five years of the act to secure a grant (Ross, 1969, p. 47). In 1890, a second Morrill Act was passed with similar guidelines. As a direct result of these reforms, by 1880 there were 85 college-level engineering schools in the country; by 1917, there were 126. And the annual number of engineering graduates rose from 100 in 1870 to 4300 by the onset of World War I (Noble, 1977, p. 24).

Beginning in the late nineteenth century, one the most powerful calls for modernization, and one that deserves special attention, came from the educational philosophy of John Dewey. Dewey, who would later be highly influential to Chinese and Japanese educators in the early twentieth century,[3] rallied against the lingering dominance of elite and classical education. Deservedly, Dewey is often credited with leading the final assault on American religious and classical education: "As the nineteenth century turned into the twentieth century the experimentation of John Dewey and his followers made it

[3]In 1919–21, Dewey performed a lecture tour in China that inspired many intellectuals to embrace his progressive ideas and his belief that the West embodied "an ideal of science and progress to which China should aspire" (Thompson, 1969, p. 131).

even more difficult for advocates of a closed intellectual system and conventional body of truth to hold their own" (Butts, 1973, p. 471). In addition, Dewey is still regarded today as *the* proponent of democratic education and education for citizenship philosophies.

Building upon the ideals of Condorcet, Jefferson, and Mann, Dewey wrote in his 1900 essay "Schooling as a Form of Community Life" that school should be thought of as a "miniature community, an embryonic society" (Dewey, 1964, p. 306). As such, Dewey recognized the need for a more "cultural" education, one that combined theory and practice, to help create more well-rounded, intelligent, and adaptable citizens:

> When the school introduces and trains each child of society into membership within such a little community, saturating him with the spirit of service, and providing him with the instruments of effective self-direction, we shall have the deepest and best guaranty of a larger society which is worthy, lovely, and harmonious (Dewey, 1964, p. 311).

These general themes throughout Dewey's writings have been continuously resurrected in educational thought and criticism. Dewey's thinking was, and still is, influential in helping to sustain an institutionalized Western education system that would not merely teach skills for a narrowly defined job or function, but also included education for citizenship and experience.

At the root of Dewey's pedagogy is his philosophy of science, a belief that the scientific methodology can be interpreted or translated into educational theory and practice, as well as in terms of human activity. This point has been de-emphasized in many of the more celebratory accounts of Dewey's pedagogy, but it is equally critical to understanding his broad outlook on educational purpose and progress:

> For more than fifty years Dewey was the chief apostle of modernity in American philosophy as well as in American education.…He argued that schools should strive to emphasize moral goals based upon democratic civic and social experience, vocational and practical usefulness, and individual development in light of the rapid modernizing changes that were taking place in Western civilization (Butts, 1973, p. 471).

Central to Dewey's thinking are the ideas of "logical" reflective thought and objectivity. Everything is subject to objective scientific scrutiny, including morality and values as well as scientific and practical affairs (Dewey, 1964, p. xix). In fact, working from the Enlightenment as a basis, Dewey refers to knowledge and morality as virtually identical concepts: "Actively to participate in the making of knowledge is the highest prerogative of man" (Dewey, 1964, p. 192). For Dewey, these beliefs are *critical* to human purpose, and all stem from his firm commitment to the scientific methodology: "One of the only two articles that remain in my creed of life is that the future of civilization depends upon the widening spread and deepening hold of the scientific habit of mind" (Dewey, 1964, p. 191).

At a deeper level, Dewey's perspective on civilizational advancement reflects the Enlightenment bias towards progress and "civilized" versus "savage" cultures. Dewey thus might be characterized as Condorcet's interpreter:

> A savage who has been shipwrecked on a river may note certain things that serve him as signs of danger in the future. But civilized man deliberately *makes* such signs; he sets up in advance of any particular shipwreck warning buoys, and builds lighthouses where he sees signs with great expertness; civilized man institutes a weather service by which signs are artificially secured and information is distributed in advance of the appearance of any signs that could be detected with special methods. A savage finds his way skillfully through a wilderness by reading obscure indications; civilized man builds a highway that shows the road to it all (Dewey, 1964, p. 214).

Although Dewey is saying civilized man uses technology to expand the capabilities inherent in the savage, and is therefore apparently not as harsh as Condorcet, he nonetheless makes a clear distinction between civilized–advanced and uncivilized–primitive based upon relative measures of technological development.

Building "civilization" is important to Dewey, and throughout his writings there is a recurrent preoccupation with the positive aspects of functional, practical tasks—the core of his educational philosophy. For Dewey, only by engaging in and thereby experiencing functional tasks, with scientific understanding, does education become truly meaningful:

> The occupation supplies the child with a genuine motive; it gives him experience at first hand; it brings him into contact with realities. It does all this, but in addition it is liberalized throughout by translation into its historic and social values and scientific equivalent. With the growth of the child's mind in power and knowledge it ceases to be a pleasant occupation merely and becomes more and more a medium, an instrument, an organ—and is thereby transformed (Dewey, 1964, p. 306).

The pedagogy of Dewey boils down to what he calls the "project method," or the active intellectual pursuit of a project and its scientific basis. Linking scientific theory and technological practice is the key component in Dewey's recommendations on education. Arousing "intellectual interest" is therefore understood by Dewey purely in terms of scientific interest; the net result being that "Theoretical subjects will become more practical, because more related to the scope of life; practical subjects will become more charged with theory and intelligent insight. Both will be vitally and not just formally unified" (Dewey, 1964, p. 425).

In the end, Dewey's legacy is as a key figure in reflecting the undercurrents of turn-of-the-century industrial America, and informing and predicting the growth of the technical disciplines in modern American education. In the twentieth century, the importance of engineering and other technical occupations is signified by the relative prestige of institutions such MIT and the California Institute of Technology. By 1913, the United States had emerged as an industrial power and had replaced Britain as the world leader in coal mining, machine tools, and chemical and automobile production (Roderick & Stephen, 1978, pp. 153–54). By that time, the ideal of education for citizenship was virtually inseparable, in practice, from education for practical occupations in the service of industrial needs.

Current Trends

The current direction of educational thought and practice concerning science and technology is a continuation of the historical precedents outlined in this essay; by World War I, all industrial powers were giving high priority to technology education. The cumulation of this trend in the twentieth century is an overvaluation of increasingly functional, professional, and corporate forms of knowledge. The gradual growth of skill-based technology education in the West grew out of an increase in the perceived need for technological advancement and the industrial power-holders need for skilled workers, especially those in engineering and related technical backgrounds. In the twentieth century, all educational disciplines (both technical and non-technical) have been increasingly scrutinized on their "use" value.[4]

In light of the Japanese high-technology competitive advancements and apparent successes in skill-based education, it is not surprising that much contemporary educational literature calls for changes needed to fix the "failing" American education system. Often, the concern in this literature is with developing "correct" educational models that will enhance skill-based learning. Of special importance is more effectively bridging academic and industrial interests, especially in high technology.[5] This is no better illustrated than by the 1995 educational pilot program of the Malcolm Baldrige Quality Award, an award originally designed exclusively for organizational improvement by profit-making companies. The pilot program is headed by both industrial and university representatives, and claims to have been "successfully" tested at all levels of education. The goal of the award is to stimulate educational process improvement using criteria very similar to the corporate quality award. "Education" is defined in practical terms—schools must prove their "effectiveness" through "measurable" results, and "learner-centered" education must account for the "real needs of learners":

> Such needs derive from the requirements of the marketplace and the responsibilities of citizenship. Changes in technology and in the national and world economies are creating increasing demands on employees to become knowledge workers and problem solvers, keeping pace with the rapid changes in the marketplace.…A learning-centered school needs to

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[4]See Noble (1977) for a discussion on the how the social sciences and humanities have also become geared to the needs of industry.
[5]See, for example, Capper & Jamison (1993) and Levin (1993).

> fully understand and translate marketplace and citizenship requirements into appropriate curricula. (*Education*, 1995, p. 3)

Given this foundation for "learning," the underlying emphasis throughout the criteria is the urgent need for building closer ties between education and industry.

It is important to recognize, however, that industrial motivations are also linked to a firm faith in technological progress. Thus, to say that technology education has merely been reduced to industrial needs, as may be exemplified most explicitly by the global proliferation of secondary and post-secondary technical institutes, is to too easily reduce the problem to industrial "interference." Furthermore, although Dewey might now argue that such an approach to education is too rigid and narrow, his definition of "creativity" also falls squarely within the scientific and technological framework—one which might be easily adapted to industrial needs. The fact remains that education and industry have nurtured each other, and it would be difficult to define the contemporary purpose of technology education solely in non-industrial terms.

Rethinking Technology education and Social Progress

Since the late Middle Ages, Western education has become widespread and institutionalized out of a historical need for skills. The process of developing and practicing mass education thus has been closely linked with the expansion of Western technological development and the pursuit of progress. Consequently, skill-based education has become critical to the survival of all disciplines, and the closer a program of study is allied to servicing the needs of our technology-driven society, the better.

Western education in the West does offer some students (usually graduate students) the prospect of engaging technology from a critical perspective. A host of humanistic philosophers and social historians in Critical Theory, Cultural Studies, Postmodernism, or other philosophy- and history-based schools of thought have brought into question Western technology and progress. But while the *practice* of technological development in modern Western society marches forward and expands into the third world, the educational attention paid to placing technology into a broader social context is paltry by comparison. Technology studies, as a specific program of study, appears to be just beyond the scope of both the technical and the non-technical disciplines, both of which remain largely content to focus on skill-based education.

Teachers of technology education, in both secondary and higher levels, are in a unique position to directly influence administration, peer, and student perceptions of the role technology in contemporary society. Technology education must seek to go beyond the transmission of the most effective and economic usage of "tools" in modern society to include critical investigations of the social purpose of technology. This means embracing a critical approach to technological issues, considering so-called humanistic and social science perspectives on the role of technology in society,[6] and empowering all students to engage in a critical dialog around technology, progress, education, and the meaning of civilizational advancement.

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Effects of Anticipation of Tests on Delayed Retention Learning

W. J. Haynie, III

The benefits of tests as aids to learning, beyond their primary evaluation function, have been studied in a variety of settings. This study sought to isolate the effects of anticipation of a test (and the assumed improvement in study and preparation commensurate with such anticipation) from the learning gains resulting from the act of taking the test. The investigation involved instruction via self-paced texts, initial testing of learning, and delayed testing three weeks later. The delayed tests provided the experimental data for the study. The investigation also included a survey to determine perceptions of students concerning classroom tests.

Background

Most of the research on testing which has been reported in recent years has concerned standardized tests, but much of the evaluation done in schools is done with teacher-made tests (Haynie, 1983, 1990a; Herman & Dorr-Bremme, 1982; Mehrens, 1987; Mehrens & Lehmann, 1987; Newman & Stallings, 1982; Stiggins, Conklin, and Bridgeford, 1986). Research is needed on the effects of teacher-made tests and other issues surrounding them such as frequency of use, quality, benefits for student learning, optimal types to employ, and usefulness in evaluation. The available findings on the quality of teacher-made tests cast some doubt on the ability of teachers to perform evaluation effectively (Carter, 1984, Fleming & Chambers, 1983; Gullickson & Ellwein, 1985; Haynie, 1992, 1995b; Hoepfl, 1994; Stiggins & Bridgeford, 1985). Despite the recognized faults, Mehrens and Lehmann (1987) point out the importance of teacher-made tests in the classroom and their ability to be tailored to specific instructional objectives. Evaluation by teacher-made tests in schools is an important and needed part of the educational system and a crucial area for research (Ellsworth, Dunnell, & Duell, 1990; Haynie, 1990a, 1992; Mehrens & Lehmann, 1987; Nitko, 1989).

The effectiveness of test taking as an aid to retention has been studied in several settings and in association with several related variables. In all of these studies, test taking has been shown to aid retention of learned material (Haynie

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1990a, 1990b, 1991, 1994, 1995a; Nungester & Duchastel 1982). Reviewers of some earlier works which used the general protocol of this study to examine the benefits of various types of tests and methods of testing/reviewing as aids to retention criticized the works by pointing out that experimental groups in many of the studies expected to be tested whereas the control groups did not. The logical argument was that students in the experimental groups paid more attention to the study of the material and thus, it was difficult to separate the gains made while studying more diligently from those claimed by the investigators to result from the act of taking the test (testing effect). Only one of those studies demonstrated a clear separation of these two factors (Haynie, 1990a), and it was conducted in a secondary school setting with videotaped materials as the teaching-learning method. Another criticism of the protocol has been that students did not expect the test scores to be counted in determination of their course grades, so they may not have taken the entire unit of instruction seriously. Lastly, in most of the earlier studies, no attempt was made to insure equal ability of the groups other than randomization of treatment assignment. This investigation examined some of the same questions as earlier studies with careful attention to address these criticisms.

Purpose and Definition of Terms

The purpose of this study was to investigate the effects of anticipation of an upcoming test and the act of taking a test as aids to retention learning. "Retention learning" as used here refers to learning which lasts beyond the initial testing and it is assessed with tests administered 2 or more weeks after the information has been taught and tested (Haynie, 1990a; Nungester & Duchastel, 1982). A delay period of three weeks was used in this study. "Initial testing" refers to the commonly employed evaluation by testing which occurs at the time of instruction or immediately thereafter. "Delayed retention tests" are research instruments which are administered 2 or more weeks after instruction and initial testing to measure retained knowledge. (Duchastel, 1981; Haynie, 1990a, 1990b, 1991, 1994, 1995a; Nungester & Duchastel, 1982). The delayed retention test results were the only data analyzed in the experimental portion of this investigation. Additionally, one group was asked to respond to a questionnaire concerning classroom testing. The responses were analyzed and are reported in this article.

The research questions posed and addressed by this study were:

1. If delayed retention learning is the objective of instruction, does initial testing of the information aid retention learning?
2. If delayed retention learning is the objective of instruction, does the anticipation of an upcoming test on the information aid retention learning?
3. Do students study with greater effort when they expect a test than when they do not expect a test?

Methodology

Population and Sample

Undergraduate students in 6 intact technology education classes were provided a booklet on new "high-tech" materials developed for space exploration. There were 110 students divided into three groups: (a) Test Announced, Test Given (Group A, *n*=37), (b) Test Announced, No Test Given (Group B, *n*=35), and (c) No Test Announced, No Test Given (Control, Group C, *n*=38). All groups were from the Technology Education metals technology (TED 122) classes at North Carolina State University. Students were freshmen and sophomores in Technology Education, Design, or in various engineering curricula. Students majoring in Aerospace Engineering were deleted from the final sample because much of the material was novel to other students but had previously been studied by these students.

Group assignment to instructor was not randomized due to scheduling restraints, however, all sections were taught by either the researcher or his graduate assistant—each teaching some control and some experimental sections. The course instructor gave no instruction or review to any groups and provided the directions for participation via a scripted standard statement. Two sections were in each group. Random assignment of groups to treatments, deletion of students majoring in Aerospace Engineering, and absences on testing dates resulted in final group sizes which were unequal. To establish equality of ability prior to conduct of the study, the means of the first subtest taken in the course were compared. This subtest on precision measurement, metallurgy, and sheet metal processes comprised the Metals Pretest.

Design

At the beginning of the course it was announced that students would be asked to participate in an experimental study and that they would be learning subject matter reflected in the newly revised course outline while doing so. The two experimental groups were both told that the test they would be given on this new material would be counted equally with the other tests in determining course grades. The control group, however, was told that formal tests had not been prepared on the added material, so this portion of the course would not be considered when determining course grades except to insure that they made a "good, honest attempt". All other instructional units in the course were learned by students working in self-paced groups and taking subtests on the units as they studied them. The subtests were administered on three examination dates. The experimental study did not begin until after the first of the three examination dates to insure that students could see (and believe) that none of the eight subtests reflected the newly added subject matter. Students' scores on the first subtest (Metals Pretest) were compared to insure that the groups were of equal ability.

During the class period following the first examination date, the subtests which had been taken were reviewed and instructions for participation in the experimental study were given. All students were given copies of a 34 page study packet prepared by the researcher. The packet was titled "High

Technology Materials" and it discussed composite materials, heat shielding materials, and non-traditional metals developed for the space exploration program and illustrated their uses in consumer products. The packet was in booklet form. It included the following resources typically found in textbooks: (a) A table of contents, (b) text (written by the researcher), (c) halftone photographs, (d) quotations from other sources, (e) diagrams and graphs, (f) numbered pages, (g) excerpts from other sources, and (h) an index with 119 entries correctly keyed to the page numbers inside. Approximately one-third of the information in the text booklet was actually reflected in the tests. The remainder of the material appeared to be equally relevant but served as a complex distracting field to prevent mere memorization of facts. Students were instructed to use the booklet as if it were a textbook and study as they normally would any class assignment.

Group A and Group B were both told to study the packet and they would be tested on the material in-class two weeks later. Both groups were requested to return the packets on the test date also. Students were told that the results would be used along with other subtest scores in determining their course grades. On the announced test date, Group A was actually administered the initial posttest, but Group B was asked to complete a questionnaire instead. Group B was then told that the test was not ready and so their highest subtest scores would be counted double in determining their grade.

In order to obtain a control group, two sections of students in the same course were given similar initial instructions, but they were not told they were in an experiment. They were merely told that the material was newly added to the course and no subtests had been prepared yet—so they were simply lucky and would be expected to study the material as if they would be tested, however, they would not actually be tested. These students comprised Group C (control).

Three weeks later, all groups were asked to take an unannounced delayed retention test on the same material. They were told at this time that the true objective of the experimental study was to see which type of test (or no test) promoted delayed retention learning best, and that their earlier tests, if any, were not a part of the study data in any way. They were asked to do their best and told that it did not affect their grades. Participation was voluntary, but all students did cooperate.

The same room was used for all groups during instructional and testing periods and while directions were given. This helped to control extraneous variables due to environment. The same two teachers provided all directions (from prepared scripts) and neither administered any instruction in addition to the texts. Students were asked not to discuss the study or the text materials in any way. All class sections met for 2 hours on a Monday-Wednesday-Friday schedule. Half of the students in each group were in 8:00 a.m. to 10:00 a.m. sections and the others were in 10:00 a.m. to 12:00 noon sections, so neither time of day nor day of the week should act as confounding variables. Normal precautions were taken to assure a good learning and testing environment.

Instrumentation

The initial test was a 20 item multiple-choice test. The items had five response alternatives. The test operated primarily at the first three levels of the cognitive domain: Knowledge, comprehension, and application.

The delayed retention test was a 30 item multiple-choice test. Twenty of the items in the retention test were alternate forms of the same items used on the initial test. These served as a subtest of previously tested information. The remaining ten items were similar in nature and difficulty to the others, but they had not appeared on the initial test. These were interspersed throughout the test and they served as a subtest of new information.

The delayed retention test was developed and used in a previous study (Haynie, 1990a). It had been refined from an initial bank of 76 paired items and examined carefully for content validity. Cronbach's Coefficient Alpha procedure was used to establish a reliability of .74 for the delayed retention test. Item analysis detected no weak items in the delayed retention test.

Data Collection

Students were given initial instructions concerning the learning booklets and directed when to return the booklets and take the test. The test (Group A) or questionnaire (Group B) was administered on the same day that the booklets were collected. The unannounced delayed retention test was administered three weeks later. Data were collected on mark-sense forms from National Computer Systems, Inc.

Data Analysis

The data were analyzed with SAS (Statistical Analysis System) software from the SAS Institute, Inc. The answer forms were electronically scanned and data stored on floppy disk. The General Linear Models (GLM) procedure of SAS was chosen for omnibus testing rather than analysis of variance (ANOVA) because it is less affected by unequal group sizes. A simple one-way GLM analysis was chosen because the only experimental data consisted of the Delayed Retention Test means of the three groups. This procedure was first applied to the first regular subtest given in the course (Metals Pretest) to determine if groups had equal entering ability. The GLM procedure was then used again with the Delayed Retention Test means. Follow-up comparisons were conducted via Least Significant Difference *t*-test (LSD) as implemented in SAS. Alpha was set at the $p<.05$ level for all tests of significance. Tabulations of frequency and percentage were the only analysis of the survey data.

Findings

The means, standard deviations, and final sizes of the three groups on the Metals Pretest and the Delayed Retention Test are presented in Table 1. The overall difficulty of the Delayed Retention Test can be estimated by examining the grand mean and the range of scores. The grand mean of all participants was 15.85 with a range of 6 to 27 on the 30 item test. No student scored 100% and the grand mean was close to 50%, so the test was relatively difficult. The grand mean, however, was not used in any other analysis of the data.

The GLM procedure was used to compare the 3 groups on the Metals Pretest to determine if they were equal in ability prior to participating in the experimental portion of the study. The means appear in Table 1. A finding of F (2, 107) = 0.29, p = .748 indicated that the groups were equal in their entering ability (Table 2).

Table 1
Means, standard deviations, and sample sizes

	Metals Pretest		Delayed Retention Test	
Treatment	Mean	*SD*	Mean	*SD*
Group A Test Announced/Given *n*=37	22.5	3.7	20.1*	3.4
Group B Test Announced/Not Given *n*=35	23.2	4.2	13.9	3.8
Group C Test Not Announced/Not Given Control *n*=38	22.8	4.1	13.5	4.2
Overall *n*=110	22.8	4.0	15.9	3.8

*Means significantly higher at the .05 level

Table 2
Comparison of group means on the metals pretest via GLM procedure

Source	D.F.	Sum of Squares	Mean Square	*F*	*p*-value	Findings
Treatments	2	9.28	4.64	0.29	.748	n.s.
Error	107	1707.71	15.96			
Total	109	1716.99				

n.s. = not significant at the p<.05 level

The GLM procedure was then used to compare the 3 treatment groups on the means of the Delayed Retention Test scores. A significant difference was found among the total test means: $F(2, 107) = 34.69$, $p<.0001$ (see Table 3).

Follow-up comparisons were conducted via *t*-test (LSD) procedures in SAS. The results of the LSD comparisons are shown in Table 1. The critical value used was $t(107) = 1.98$, $p<.05$. The mean of the tested experimental group, Group A (Test), was significantly higher than either non-tested group, Group B (No Test) and Group C (Control). This was a clear demonstration of testing effect—the act of taking the test helped students retain the information. The means of Groups B and C, however, did not differ significantly from each other even though Group B expected to be tested and graded on the material.

Table 3
Comparison of group means on the delayed retention test via GLM procedure

Source	D.F.	Sum of Squares	Mean Square	*F*	*p*-value	Findings
Treatments	2	1016.59	508.29	34.69	.0001	*
Error	107	1567.78	15.96			
Total	109	2584.37				

*Significant at the p<.05 level

The results of the survey administered to Group B are shown in Table 4. Only 11% of the students claimed that they would study if they did not expect a test. Nearly a third of the students reported that they consider themselves to be "test anxious beyond the level of most normal students." Other findings from the survey concerning which types of tests students prefer and which types they believe are most accurate for evaluation are also shown in Table 4.

Discussion

Three research questions were addressed by this study:

1. If delayed retention learning is the objective of instruction, does initial testing of the information aid retention learning? Within the constraints of this study, testing of instructional material did promote retention learning. This finding, a clear demonstration of testing effect, has been very consistent among several studies (Haynie 1990a, 1990b, 1991, 1994, 1995a; Nungester & Duchastel, 1982).

2. If delayed retention learning is the objective of instruction, does the anticipation of an upcoming test on the information aid retention learning? In some previous studies using a similar protocol the question was raised by reviewers whether it was the actual act of taking the test which aided retention learning or if the knowledge that a test was forthcoming motivated students to study more effectively. This was a central research question of one previous study (Haynie, 1990a) in which announcements of the intention to test were evaluated and shown not to be effective in promoting retention learning unless they were actually followed by tests or reviews. That finding was clearly repeated here because only the group which was actually tested (Group A) outscored the control group (Group C)—the students who expected a test but did not actually take the test (Group B) scored no better on retention than the control group which expected no test. Reviewers also criticized the previous studies because students in all groups had been told that their efforts would not count in their course grades, so they likely did not take a serious approach to their study of this unit. In this investigation, however, both of the experimental groups (A and B) did expect their scores on the immediate posttest to be counted in

determination of their course grades. Despite the fact that Group B expected a test to be given and expected it to be counted in their course grades, they were

Table 4
Results of survey on testing from Group B

	Yes		No	
Item Stem	#	%	#	%
I would study if there was no test expected	4	11.4	31	88.6
I am test anxious	11	31.4	24	68.6
I prefer this type of test:				
Take-Home	28	80.0	7	20.0
Multiple-Choice	31	88.6	4	11.4
True-False	9	25.7	26	74.3
Short Answer	15	42.9	20	57.1
Essay-Discussion	11	31.4	24	68.6
Matching	22	62.9	13	37.1
This type of test is more accurate:				
Take-Home	8	22.9	27	77.1
Multiple-Choice	18	51.4	17	48.6
True-False	3	8.6	32	91.4
Short-Answer	32	91.4	3	8.6
Essay-Discussion	29	82.9	6	17.1
Matching	12	34.3	23	65.7

n=35, Only Group B was surveyed

still outscored significantly by Group A. Since the metals pretest showed the groups to be of equal entering ability and everything else about the courses and treatments were the same, the only identifiable difference between these two groups was that Group A may have moved more information from short term to long term memory while they were engaged in the act of taking the test (testing effect), but Group B did not show these gains simply due to their supposed increased study or motivation—only actual testing brought about increased retention. This finding is consistent among the previous studies in this series, even though most of those studies did have the flaws mentioned above.

3. Do students study with greater effort when they expect a test than when they do not expect a test? In this study, the group which was told they would be tested but did not actually take the test did not show any gains in retention over the control group. This finding was consistent with a similar study by Haynie (1990a). However, in answer to an item on the survey, over 88% of the students reported that they would not study material unless they expect it to be reflected on a test—this would support the practice of administering regular preannounced tests to provide external motivation for students to study.

Other findings from the survey included: Students prefer take home, multiple-choice, and matching tests; but they acknowledge that take home and matching tests probably do not test knowledge very accurately. Additionally, about a third of the students feel test anxious, so there may be differential effects of the "pressure of a looming test" for these students vs. non test anxious students.

The conclusion here is that, in general, students do likely *study more earnestly* when they expect a test than if they do not, but maximum benefit in retention is gained only by having students anticipate and then actually take a test. The idle threat of an upcoming test did not result in increased retention for Group B in this study or in the earlier one (Haynie, 1990a), only Group A which was tested actually retained more knowledge after a delay of three weeks. Most readers will rightly assume that a large portion of the gains demonstrated here were due to simple testing effect (when a student takes the same test or an alternate form of a test a second time, the score is likely to increase). However, one-third of the information on the delayed retention test used in these studies is not reflected in any way on the initial posttests. The gains in retention were demonstrated by Group A in both the previously tested and the novel items of the delayed retention test. Group A scored 18 percentage points higher on the previously tested material and 23 percentage points higher on the novel material than did Group B, while Group B showed no gains over the control Group C in either subsection of the delayed retention test. Thus there is some evidence here that the gains may exceed those normally associated with simple testing effect. Therefore, this researcher concluded that being tested helps students to retain information while simply being warned of a test and expecting a grade does not.

Recommendations

Since testing consumes such a large amount of teacher and student time in the schools, it is important to learn as much as possible about the effects of tests on learning. It is important to maximize every aspect of the learning and evaluation process. The ability of teachers to develop and use tests effectively has been called into question recently, however, most research on testing has dealt with standardized tests. The whole process of producing, using, and evaluating classroom tests is in need of further research.

This study was limited to one educational setting. It used learning materials and tests designed to teach and evaluate a limited number of specified objectives concerning one body of subject matter. The sample used in this study may have been unique for unknown reasons. Though the present study did support findings of a study in a different setting, they must be replicated in numerous settings and via differing methods before they can be accepted. Therefore, studies similar in design which use different materials and are conducted with different populations will be needed to achieve more definite answers to these research questions. However, on the basis of this one study, it is recommended that: (a) when useful for evaluation purposes, classroom testing should continue to be employed due to its positive effect on retention learning, and (b) students should know in advance that they will be tested because of the effect this information may have on their study habits. The time devoted by teachers and students to classroom testing apparently does have learning value in addition to its utility for evaluation purposes.

The value of tests in promoting retention learning has been demonstrated here and research questions about anticipation of tests have been addressed, however, there remain many more potential questions about classroom testing. The tests used in this study were carefully developed to resemble and perform similarly to teacher-made tests in most regards, however, there are still research questions which must be answered only on the basis of tests actually produced by teachers and for use in their natural settings.

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The Design of an Instrument to Assess Problem Solving Activities in Technology Education

Roger B. Hill

Literally millions of dollars have been spent during recent years to build and equip new or renovated technology education laboratories and to implement contemporary instructional strategies (R. Barker, personal communication, February 14, 1997). For instance, in the state of Georgia alone, over $23.9 million dollars has been spent since 1989 on modular-type programs (Gossett, 1997). Modular curriculum designs have been widely adopted and the integration of math, science, and technology explored. Modular designs typically provide students, working in pairs, opportunities to progress through a series of guided learning activities with an emphasis on problem solving and a hands-on, minds-on approach to learning about technology. Modular lessons are available to address over twenty different specific technological topics and more are being developed on a regular basis.

Although adoption of modular curriculum models is one of the most visible trends in contemporary technology education, other significant issues are also impacting the profession. In particular, efforts to equip students with the ability to solve problems, to think analytically, and to apply technical knowledge to real world situations have become integral to technology education (Technology for All Americans Project, 1996). Whether using a modular approach, a traditional unit lab approach, or some other organizational strategy for instruction, problem solving activities are a relevant and important part of technology education.

Proponents of adopting modular curriculum programs for technology education have cited numerous anecdotal accounts in support of the value and accomplishments of their programs, but systematic methods of defining and measuring student outcomes have not been sufficiently developed. As a result, the assessment of modular technology education programs and instruction has not been adequately implemented to guide allocation of resources, substantiate curriculum change, and establish the value of these educational activities within the larger educational community. While similar concerns might be raised about other trends in education, the movement toward modular curriculum designs in technology education has been one of the most prominent and significant issues for technology education professionals.

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The Need for Assessment

Assessment is a process that uses information gathered through measurement to analyze or judge a learner's performance on some relevant work task (Sarkees-Wircenski & Scott, 1995). The process can also be applied to a systematic examination of materials, programs, or activities for the purpose of formulating a value judgement about their suitability for a particular application. Procedures used in performing an assessment should be predicated upon a clear understanding of goals for instruction and the desired learning outcomes, whether assessing learner performance or some other aspect of the learning environment. Just as a compass on a ship allows the captain to determine direction of travel and make course corrections, assessment provides the feedback needed by an instructor to successfully guide student learning activities.

In response to public and political pressure to assure accountability and reduce expenditures, assessment of educational programs is viewed as being increasingly important (Lewis, 1995; Sewall, 1996). It is therefore essential that technology education professionals be equipped with tools to effectively assess how instructional materials and teaching methodologies are facilitating learning (Custer, 1996).

Assessment of technology education must go beyond the tacit approval sometimes afforded after a cursory look at facilities and activities. Whether observing the spellbound visitors on the floor of the annual ITEA Conference Trade Show or the expressions of awe from first-time visitors to recently renovated technology labs, it is evident that fascination with technological gadgetry can initially occur. Caution must be used so that this effect does not overshadow the outcomes that technology education should be producing. Students who successfully participate in technology education activities should develop a number of intellectual qualities including "understanding and competence in designing, producing, and using technology products and systems, and in assessing the appropriateness of technological actions" (Wright & Lauda, 1993, p. 4). Creating appropriate assessment strategies as well as establishing effective technological literacy efforts at each level of schooling should be a primary goal of the profession (Technology for All Americans Project, 1996).

A key element in the study of technology and the development of technological literacy is the task of solving problems. The Technological Method Model (Savage & Sterry, 1990), described in the *Conceptual Framework for Technology Education*, spoke to the issues of how humans use technology to solve problems. This model specifically addressed problem solving as an essential component to working and competing in the modern day workforce. The professional literature in the field of technology education is replete with references to problem solving and the importance of this intellectual process within the contemporary world (Johnson, 1987, 1994; McCade, 1990; Shlesinger, 1987; Tidewater Technology Associates, 1986; Waetjin, 1989). Therefore it is imperative that professionals in the field incorporate problem solving concepts and strategies as a significant element in curriculum design and implementation.

The task of solving problems can be undertaken in a variety of ways. Problem solving can be approached from simple trial-and-error efforts and range on a continuum to highly complex approaches. Many technology educators espouse the need to create opportunities for students to learn multiple approaches to problem solving with movement toward the development of models to facilitate student growth in strong mental methods of inquiry when solving technological problems (Herschbach, 1989; Hutchinson & Hutchinson, 1991; Todd, 1990; Wicklein, 1993; Zuga, 1989).

One of the aspects that should distinguish technology education from other program areas that address technological content is the integrated study of technological processes, knowledge, and context. In presenting *A Rationale and Structure for the Study of Technology*, the Technology for all Americans Project (1996) identified these three components as universals for the study of technology. Knowledge related to technology, and processes related to technology, are taught within the context of manipulative activities with information, physical, or biological systems. Hands-on activities are important, but they are not aimed toward development of vocational competencies. They provide a setting for experiential learning related to technology. Of significance to this study, knowledge of technology and manipulative skills related to technology are relatively easy to measure and assess. Use of technological processes, with associated thinking and problem solving skills, is often challenging to measure and accurately assess.

Mental Processes as a Basis for Assessment

Halfin (1973) conducted the seminal research that identified the mental process used by practicing technologists. Beginning with a review of the writings of ten high-level technologists; including persons such as Thomas Edison, Frank Lloyd Wright, and Buckminster Fuller; Halfin identified, and used a Delphi technique to validate 17 processes which were universal to the work of technological professionals. Wicklein (1996) has since undertaken a follow-up study to re-evaluate these processes and further define each of them. In both instances, research was conducted for the benefit of industrial arts or technology education professionals, but the work would be applicable to anyone with an interest in the mental processes used by technologists.

The processes identified by Halfin were operationally defined in his work. In addition, Wicklein developed examples for each of the mental processes to more clearly describe their meanings so that each could be discriminated from the other (Hill, 1996). This task was completed following a thorough study of Halfin's work. Wicklein used these operational definitions and examples in developing instrumentation used to re-evaluate the mental processes, but these materials were also a critical element in the development and use of the assessment described here. Table 1 lists the mental processes and operational definitions developed by Halfin for each of the mental processes.

From a practical perspective, the mental processes used by practitioners in technological occupations provide a useful guide for the assessment of instructional activities and content in technology education programs. In some respects, basing curriculum content on mental processes, a relatively constant set of constructs, is more logical than focusing on technological products which are constantly changing. Instructional use of mental processes and product technologies are not mutually exclusive. Technology education inherently includes hands-on experiences with materials and instruction about technical content. When considered in the proper perspective, however, content related to materials and technical processes is characterized by rapid obsolescence while technological mental processes remain relatively stable and continue to be useful for many years. Both should be included in technology education instruction, but the primary emphasis should be placed on the mental processes.

Table 1
OPTEMP codes and definitions for Halfin's mental processes

Code	Mental Process and Definition
(DF)	*Defining the Problem or Opportunity Operationally*. The process of stating or defining a problem that will enhance investigation leading to an optimal solution. It is transforming one state of affairs to another desired state.
(OB)	*Observing*. The process of interacting with the environment through one or more of the senses. (Seeing, hearing, touching, smelling, and tasting.) The senses are utilized to determine the characteristics of a phenomenon, problem, opportunity, element, object, event, system, or point of view. The observer's experiences, values, and associations may influence the results.
(AN)	*Analyzing*. The process of identifying, isolating, taking apart, breaking down, or performing similar actions for the purpose of setting forth or clarifying the basic components of a phenomenon, problem, opportunity, object, system, or point of view.
(VI)	*Visualizing*. The process of perceiving a phenomenon, problem, opportunity, element, object, event, or system in the form of a mental image based on the experience of the perceiver. It includes an exercise of all the senses in establishing a valid mental analogy for the phenomena involved in a problem or opportunity.
(CO)	*Computing*. The process of selecting and applying mathematical symbols, operations, and processes to describe, estimate, calculate, quantify, relate, and/or evaluate in the real or abstract numerical sense.
(CM)	*Communicating*. The process of conveying information (or ideas) from one source (sender) to another (receiver) through a media using various modes. (The modes may be oral, written, picture, symbols, or any combination of these.)
(ME)	*Measuring*. The process of describing characteristics (by the use of numbers) of a phenomenon, opportunity, element, object, event,

system, or point of view in terms which are transferable. Measurements are made by direct or indirect means, are on relative or absolute scales, and are continuous or discontinuous.

(PR) *Predicting*. The process of prophesying or foretelling something in advance, anticipating the future on the basis of special knowledge.

(QH) *Questioning and Hypothesizing*. Questioning is the process of asking, interrogating, challenging, or seeking answers related to a phenomenon, problem, opportunity, element, object, event, system, or point of view. Hypothesizing is a process of stating a theory of tentative relationship between two or more variables to be tested which are aspects of a phenomenon, problem, opportunity, element, object, event, system, or point of view.

(ID) *Interpreting Data*. The process of clarifying, evaluating, explaining, and translating to provide (or communicate) the meaning of particular data.

(MP) *Constructing Models and Prototypes*. The process of forming, making, building, fabricating, creating, or combining parts to produce a scale model or prototype.

(EX) *Experimenting*. The process of determining the effects of something previously untried in order to test the validity of a hypothesis, to demonstrate a known (or unknown) truth or try out various factors relating to a particular phenomenon, problem, opportunity, element, object, event, system, or point of view.

(TE) *Testing*. The process of determining the workability of a model, component, system, product, or point of view in a real or simulated environment to obtain information for clarifying or modifying design specifications.

(DE) *Designing*. The process of conceiving, creating, inventing, contriving, sketching, or planning by which some practical end may be effected, or proposing a goal to meet the societal needs, desires, problems, or opportunities to do things better. Design a cyclic or iterative process of continuous refinement or improvement.

(MO) *Modeling*. The process of producing or reducing an act, art, or condition to a generalized construct which may be presented graphically in the form of a sketch, diagram, or equation; presented physically in the form of a scale model or prototype; or described in the form of a written generalization.

(CR) *Creating*. The process of combining the basic components or ideas of phenomena, objects, events, systems, or points of view in a unique manner which will better satisfy a need, either for the individual of for the outside world.

(MA) *Managing*. The process of planning, organizing, directing, coordinating, and controlling the inputs and outputs of the system.

A major impediment in past efforts to assess technology education outcomes has been the difficulty of defining and measuring such abstract concepts as technological literacy and problem solving ability. This dilemma has been exacerbated by the mindset of ex-post facto assessment. The typical pattern has been to provide some type of instructional experience or treatment and then to test participants for learning outcomes. New forms of assessment, such as portfolios and journals, are gaining acceptance and are intended to enhance the learning process in addition to providing evidence of learning (Kane & Khattri, 1995; Travis, 1996). Unless actual development of materials is observed in some purposeful manner, however, even portfolios do not provide a means of assessing learning activities as they occur.

Educational research, particularly within the field of cognitive psychology, has provided a theoretical framework upon which to base an alternative form of assessment. In particular, research has shown a clear relationship between teaching behaviors and student achievement (Brophy & Good, 1986). Teaching behaviors include not only the actions of the teacher, but the instructional activities facilitated by that teacher. With this as a premise, alternative forms of assessment can be considered. Rather than only testing after learning activities are completed, assessment can be conducted *during* the learning activities. Used in conjunction with traditional forms of testing, this form of assessment holds great potential to provide additional feedback regarding the learning process. If outcomes measured in ex-post facto testing are substandard, data gathered *during* the learning process can be used to analyze the causal factors. In addition, such a tool could assess processes that are not conducive to traditional testing, either due to lack of an appropriate test or because such tests are not sensitive enough to accurately measure the outcomes.

The purpose of this research was to develop and field test a technique for assessing the mental processes used by students as they participate in instructional learning activities in technology education. The technique focused on mental processes used by technology practitioners in their work, as identified by Halfin (1973), and provided an objective measurement that could be used to assess the procedural content *during* a learning activity. The processes developed in this study can be readily applied to programs that use a modular approach in instruction because of the relatively structured activities included, the focus on problem solving, and a level of student movement that is conducive to observation. The technique, however, could be adapted and used with other forms of instructional problem solving activities. The results would be relevant for any program focused on development of mental processes, of the type used by practicing professional technologists, for problem solving.

Method

The focal point of the assessment tool developed through this research was a measure of the duration and the frequency of selected mental processes necessary for effective problem solving used by students in the completion of technology education learning activities. The tasks necessary to accomplish this included (1) developing a procedure for identifying the mental processes as they were used by students, (2) creating a tool to aid in analyzing the duration and frequency of the mental processes used by students, and (3) testing the system for consistency and reliability.

It is relevant to note that while the term assessment often is used within a context where a value judgement is made and one thing is determined to better than another, the process described in this study uses the term operationally to describe procedures for identifying particular activities, determining how long these activities last, and how frequently activities are repeated in practice. The procedure would enable an observer to determine whether a learning activity accomplished objectives related to use of mental processes in problem solving. It was not, however, designed to directly measure the products or outcomes of the activities involved.

For purposes of this study, the mental processes identified by Halfin (1973) were used. A document was assembled in which a definition was stated and examples were listed for each of these processes. This document provided a ready reference to clarify each of the processes and was frequently referred to during the assessment procedures. Two-letter codes were also developed for each of the mental processes to be used for recording purposes. Table 1 provides a list of the two-letter codes, the mental processes, and their definitions. The document used during the study also included from 6 to 10 behavioral examples for each of the mental processes. It was not included in this manuscript for the sake of brevity, but a copy of it can be obtained directly from the author.

The basic procedure for identifying which mental processes were being used by students consisted of carefully studying the written materials and instructions for a particular learning activity, and then observing students as they completed the activity. Videotapes of students completing modular technology education learning activities were used for the development of the assessment procedure reported in this study. This was necessary to be able to test for consistency and reliability of the assessment procedure. With appropriate instruction and experience, it was anticipated that the assessment procedure could be performed during a live observation session if preferred. It should be noted that it was necessary to view the students themselves, the written materials they were following, the apparatus being used by the students, and to hear the student conversations in order to accurately identify the mental processes being used.

Three pairs of subjects were videotaped for purposes of this study. All students attended a high school or middle school located in the southeastern United States. One pair of male high school students, one pair of male middle school students, and one pair of middle school students consisting of a male and female were voluntary participants for the study. High school students were videotaped as they completed two activities of a construction module prepared by a commercial vendor of technology modules and equipment. The middle school students were videotaped as they worked through two activities of a color computer-aided publishing module produced by a supplier of computer peripherals. These activities covered word processing fundamentals and page layout. The authors who developed the computer-aided publishing module were experienced technology educators with a combined total of 28 years in the profession. The equipment used by the middle school students in the module consisted of a desktop microcomputer, desktop publishing software, and a color ink-jet printer.

To field test the assessment procedure, written materials for the instructional activities were first carefully reviewed and notations were made, using the two-letter mental process codes listed in Table 1, to identify the mental processes students were likely to use at various points during the lesson. The list of mental processes with codes, operational definitions, and behavioral examples was kept at hand during the actual assessment procedure.

Preliminary testing of the observation procedure was done using a timer to record the duration and frequency of each mental process observed. Two independent observers completed two observation procedures each using the videotape of the two high school students working with the construction technology module. This phase of field-testing demonstrated that agreement could be achieved between observers independently viewing videotaped technology education activities. In this initial test, rate of agreement was 100% for identifying the mental processes being used and the duration and frequency measures were within an 80% rate of agreement for the two independent observers. The recording process was cumbersome, and the tabulation of long observations tedious.

In response to difficulties noted in the preliminary testing phase, a computer program was developed to provide a tool for recording and analyzing the duration and frequency of use of the various mental processes by students. The function of the computer was to serve as both a timer and a counter, allowing the observer doing the assessment to simply key in the two-letter mental process codes as they were observed, and having the computer to tabulate the results upon completion. The program, written by the principal investigator of the study and coded in BASIC, was named Observation Procedure for Technology Education Mental Processes (OPTEMP).

The refined assessment procedure was initiated by running the OPTEMP program and selecting the *Mental Processes Measurement* option from the main menu. After responding to some questions related to observation subject and observer, timing was ready to start. The videotape was turned on and as actions reflecting various mental processes were observed, the two-letter codes were keyed into the computer. With each change of activity, mental process codes were entered. The computer program timed each event, tallied the frequency for each, and following completion of the session provided a printed summary for each mental process code entered.

To establish reliability of the OPTEMP procedure, two observers independently observed and recorded the duration and frequency of mental processes using the three videotaped sessions of middle school students completing activities using the computer-aided publishing module. Prior to beginning the first observations, the modular materials used by the students were reviewed and the observers discussed definitions of the mental processes. Observer 2 found it helpful to classify and label the anticipated mental processes in the instructor copy of the printed materials used by the students. This observer made adjustments and additions as the videotape was viewed, but the initial analysis aided the accuracy of the final observations recorded.

The first OPTEMP observation was completed using videotape of the male and female middle school students completing a page layout activity. The additional observations used videotapes of the male and female middle school students completing a word processing activity and the two male middle school students completing the page layout activity. The typical pattern used by the students as they worked together was for one student to read aloud the instructions and identify the significant steps while the other student worked with the computer. They worked together in this manner throughout each of the activities and discussed the instructions provided in the module as they completed the steps described there.

Results

The summary reports were the key artifacts used in assessing the outcome of the three videotaped field tests analyzed using the OPTEMP. The total duration in minutes and a frequency count was recorded for each mental process as interpreted independently by the two observers. Table 2 provides the results for the first test of inter-rater reliability. Pearson correlation coefficients were calculated to determine how reliable the OPTEMP results were for the two independent observers. The correlation coefficient for overall duration on the mental processes observed in the first inter-rater reliability test was .94 and the correlation coefficient for frequency was .95 (see Table 3). There were two discrepancies in the mental processes coded, with observer 1 coding instances of analysis and observer 2 coding experimenting. In addition, a 2.39 minute difference in total duration for the procedure indicated a need for better cueing of the videotaped session.

Results from the second inter-rater reliability test are presented in Table 4. The correlation coefficient for duration in this test was .88 and the correlation coefficient for frequency was .92. Two discrepancies in mental processes occurred with observer 1 recording experimenting and observer 2 recording instances of creating. Overall durations for the two observations were approximately equivalent for this session.

The results for a third inter-rater reliability test produced a correlation coefficient of .93 for duration and a correlation coefficient of .91 for frequency. The observers were in agreement concerning the mental processes that were observed (see Table 5) and the overall durations of the observations were suitably close.

Observer 1 completed a test and re-test for the videotaped session used in the first inter-rater reliability test, the tape of male and female students completing the page layout activity. The results of this test are presented in Table 6. The correlation coefficient for duration in this repeated test was .95 and the correlation coefficient for frequency was .97. One discrepancy in mental processes occurred with instances of experimenting being observed during the second viewing of the videotape.

Table 2
Inter-rater reliability for OPTEMP used by two independent observers with male and female middle school students completing page layout activity

Mental Process	Obs. 1 Time	Obs. 2 Time	Obs. 1 Freq.	Obs. 2 Freq.
DF	1.70	2.33	3	3
OB	.77	.65	7	3
AN	.42	--	5	--
CM	7.65	5.30	34	18
ME	2.18	2.98	10	8
QH	1.33	.75	11	5
MP	7.53	5.98	26	20
EX	--	.75	--	4
CR	3.40	3.85	4	2
Totals	24.98	22.59	100	63

Note. Time is in minutes. Obs.=Observer; Freq.=Frequency

Table 3
Pearson correlation coefficients for observations using OPTEMP

Observation	Pearson Correlation Coefficient for Duration	Pearson Correlation Coefficient for Frequency
Inter-rater Reliability for Two Observers with Male and Female Completing Page Layout Activity	.94	.95
Inter-rater Reliability for Two Observers with Male and Female Completing Word Processing Activity	.88	.92
Inter-rater Reliability for Two Observers with Two Males Completing Page Layout Activity	.93	.91
Repeated Observations by Same Observer with Male and Female Completing Page Layout Activity	.95	.97

Table 4
Inter-rater reliability for OPTEMP used by two independent observers with male and female middle school students completing word processing activity

Mental Process	Obs. 1 Time	Obs. 2 Time	Obs. 1 Freq.	Obs. 2 Freq.
DF	.88	1.95	5	8
OB	2.32	.97	20	6
AN	1.23	.97	10	3
CM	9.17	9.18	45	36
ME	1.13	1.38	5	3
QH	2.02	3.77	16	15
MP	9.32	6.80	43	27
EX	1.23	--	2	--
TE	5.28	4.38	1	4
DE	--	.48	--	3
CR	1.43	4.20	2	7
Totals	34.01	34.08	149	112

Note. Time is in minutes. Obs.=Observer; Freq.=Frequency

Table 5
Inter-rater reliability for OPTEMP used by two independent observers with two male middle school students completing page layout activity

Mental Process	Obs. 1 Time	Obs. 2 Time	Obs. 1 Freq.	Obs. 2 Freq.
DF	.60	1.38	7	5
OB	3.63	.97	43	12
AN	2.02	1.12	24	7
CM	11.88	13.43	80	64
ME	1.82	3.58	16	13
QH	1.27	.83	14	8
MP	10.77	8.57	76	39
EX	.85	1.12	4	4
CR	.68	2.28	4	7
Totals	33.52	33.28	272	159

Note. Time is in minutes. Obs.=Observer; Freq.=Frequency

In addition to the numerical results reported in the tables, several conclusions were noted regarding the OPTEMP system. Both observers found that use of the procedure caused them to analyze *what* was happening during the technology education instructional activities in a more detailed manner than they had done so before. They also noted that the nature of the modular curriculum materials aided the process because the observer could become familiar in advance with the basic path the students would follow and this facilitated identification of most of the mental processes that would be used by students.

The overall agreement among independent observers regarding which mental processes were being used provided some evidence that the OPTEMP was valid. To provide additional evidence of validity, feedback from students about their own interpretation of the mental processes being used during technology education activities could be obtained and compared with the OPTEMP results. This technique was precluded in the present study due to the young age of the middle school participants and their limited understanding of the mental processes as defined, but upper level high school or post-secondary students would be capable of comprehending and distinguishing their own use of the mental processes.

Table 6
Observation times and frequencies for OPTEMP repeated by the same observer for male and female middle school students completing page layout activity

Mental Process	1st Obs. Time	2nd Obs. Time	1st Obs. Freq.	2nd Obs. Freq.
DF	1.70	1.50	3	5
OB	.77	1.35	7	16
AN	.42	.63	5	5
CM	7.65	8.82	34	44
ME	2.18	2.08	10	15
QH	1.33	.87	11	10
MP	7.53	8.28	26	38
EX	--	.42	--	3
CR	3.40	.92	4	6
Totals	24.98	24.87	100	142

Note. Time is in minutes. Obs.=Observer; Freq.=Frequency

Conclusion and Recommendations

Based on the inter-rater reliability test results and the repeated test results, the OPTEMP was determined to be an effective tool for assessing the use of mental processes during completion of modular technology education learning activities. The data gathered using this technique would enable an instructor or researcher to accurately determine which mental processes, used by practicing technologists, were being implemented by technology education students. Activities could be modified and further assessed to incorporate key processes not being used and changes could be made to adjust the duration and frequency of processes presently in use.

The use of modular technology education instructional activities in the development and testing of the OPTEMP facilitated this study because students working in that environment were readily available, limited physical movement facilitated videotaping, and instructional content incorporated numerous instances for problem solving. The specific comments provided in the remainder of this section reference the use of modular curriculum materials, but these are not intended to preclude the use of the OPTEMP with other instructional formats.

These comments are also based on two key assumptions. The first is that duration and frequency of using a mental process are related to learning outcomes specific to that process. In other words, the more someone uses a mental process, the better one will be at using that mental process. The other assumption is that it is appropriate for technology education to facilitate student development of mental processes used by practicing technologists. Halfin (1973) and Wicklein (1993, 1996) have provided a sound rationale for this.

The modular technology education lessons used in this study were not purposefully designed to provide students with opportunities to apply the mental processes identified by Halfin. As is the case with all well-designed technology education modules, problem solving activities were included. Incidental to that, uses of mental processes were involved in the work necessary to complete the instructional activities. The OPTEMP has significant value for technology education professionals who intend to encourage development of mental processes in some deliberate way. By providing a tool for assessing the process content of modular learning activities, the OPTEMP facilitates comparison of the various instructional products on the market and makes possible more informed choices about use of scarce educational resources.

Further development and revision of previously installed technology education modules is another area of concern for most practicing technology educators. These changes and enhancements are typically guided by problems such as apparatus not working correctly, student confusion about instructions, or time requirements for an activity. Use of the OPTEMP could further enhance revisions of existing materials. By identifying mental processes with less duration and frequency of use, revisions could be directed to provide problem solving experiences that include a more balanced treatment of the mental processes used by technologists.

The OPTEMP could find meaningful use in the preparation of technology education teachers. In considering curriculum design and other related issues, the observer using the OPTEMP would gain a heightened awareness of what is really happening for students as a learning activity is conducted. Just as a color or other characteristic of an object can go unnoticed unless attention is called to it, student learning activities can be observed but not really understood in the absence of a systematic approach for analysis. Use of the OPTEMP during curriculum classes, intern experiences, and perhaps as a tool during student teaching could enhance the preparation of future technology education teachers.

Wicklein (1993) has proposed development of a process-based technology education curriculum. In such a design, technology education instructional activities would be organized around the mental processes of technologists rather than around a product-based technology. Content related to communication, transportation, manufacturing, and construction would still be included, but the arrangement of this content would differ. Goodlad (1966) recommended designing curriculum that had a systematic, carefully considered approach, but not necessarily a step-by-step sequence of topics in ascending order of difficulty. Structuring curriculum around the mental processes would emphasize the more permanent constructs associated with thinking and problem solving. Technical content would be included, but specific skills and knowledge of materials would be presented with the understanding that changes could be quickly expected. Emphasis on the relatively stable mental processes would provide learning experiences that would have lasting value for students.

For those that would develop and adopt a process-based approach to curriculum, the OPTEMP provides a readily available assessment tool for analyzing the results. Instructional materials designed around traditional approaches to technology education can be evaluated, but the instrument aligns with the stated purpose of process-based materials and would therefore provide a more accurate assessment of their effectiveness.

In this initial work with the OPTEMP, the focus was directed more toward the design of the learning activities than on individual learner performance. Further research is needed to explore uses of the OPTEMP for assessment of learning outcomes. At present no claim has been made other than that OPTEMP scores indicated the duration and frequency of mental processes that students used as they went about the problem solving activities included in technology education learning activities. It is anticipated that correlation between OPTEMP scores for student use of appropriate mental processes and gain scores on established tests would be moderate to high. Those students who spend time off task or who make significant use of inappropriate mental processes would be expected to be less efficient in their learning about technology. Use of the OPTEMP in conjunction with traditional tests might produce a diagnostic assessment which would aid in helping students develop more effective work habits and learning strategies.

Additional testing of the OPTEMP beyond this initial study is also needed to address issues of variability. Use of the procedure by a greater variety of observers and with different types of students, perhaps with differing cultural backgrounds, is requisite to further establishing reliability and validity. In addition, further testing with several additional types of modular technology education activities, and perhaps with other instructional strategies that incorporate problem solving, would determine the versatility of the procedure. The study described here has provided a description of the procedure and offered results of initial testing, but much additional work is needed to verify the usefulness of the OPTEMP and to further refine procedures for its application.

The issue of assessment will be of critical importance to every area of the educational enterprise as the new century dawns (Stiggins, 1995). The assessment system developed and tested in this study was shown to hold promise as a reliable and useful tool for analyzing important components of technology education problem solving activities and should be of benefit to the profession. The potential benefits range from aiding the identification of quality instructional materials to assisting in the preparation of technology education teachers. As previously mentioned, work is needed to further refine the OPTEMP procedures, to enhance the computer program, and to establish validity and utility of the system. Without adequate assessment procedures, technology education cannot reach its full potential and it will continue to struggle for recognition and acceptance within the greater educational community.

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Choosing Qualitative Research: A Primer for Technology Education Researchers

Marie C. Hoepfl

A number of writers have commented on the dearth of substantive research within the field of technology education, and point to the expansion of its research agenda as a means of strengthening the discipline. Waetjen, in his call for good research in technology education, states that "the plea is to use experimental type research as much as possible" (1992, p. 30). Interestingly, the three areas of research need outlined in his essay would all lend themselves to alternative methodologies, including qualitative methodologies.

More recently, others have called for an expansion in the types of research methods used. Of the 220 reports included in Zuga's review of technology education-related research (1994), only 16 are identified as having used qualitative methods, and Zuga notes that many of those studies were conducted outside the United States. Johnson (1995) suggests that technology educators "engage in research that probes for deeper understanding rather than examining surface features." He notes that qualitative methodologies are powerful tools for enhancing our understanding of teaching and learning, and that they have "gained increasing acceptance in recent years" (p. 4).

There are compelling reasons for the selection of qualitative methodologies within the educational research arena, yet many people remain unfamiliar with these methods. Researchers trained in the use of quantitative designs face real challenges when called upon to use or teach qualitative research (Stallings, 1995). There is, however, a growing body of literature devoted to qualitative research in education, some of which is synthesized here. The goals of this article are to elaborate on the reasons for choosing qualitative methodologies, and to provide a basic introduction to the features of this type of research.

Qualitative Versus Quantitative Research Paradigms

Researchers have long debated the relative value of qualitative and quantitative inquiry (Patton, 1990). Phenomenological inquiry, or qualitative research, uses a naturalistic approach that seeks to understand phenomena in context-specific settings. Logical positivism, or quantitative research, uses experimental methods and quantitative measures to test hypothetical

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generalizations. Each represents a fundamentally different inquiry paradigm, and researcher actions are based on the underlying assumptions of each paradigm.

Qualitative research, broadly defined, means "any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification" (Strauss and Corbin, 1990, p. 17). Where quantitative researchers seek causal determination, prediction, and generalization of findings, qualitative researchers seek instead illumination, understanding, and extrapolation to similar situations. Qualitative analysis results in a different type of knowledge than does quantitative inquiry.

Eisner points out that all knowledge, including that gained through quantitative research, is referenced in qualities, and that there are many ways to represent our understanding of the world:

> There is a kind of continuum that moves from the fictional that is "true"—the novel for example—to the highly controlled and quantitatively described scientific experiment. Work at either end of this continuum has the capacity to inform significantly. Qualitative research and evaluation are located toward the fictive end of the continuum without being fictional in the narrow sense of the term (Eisner, 1991, pp. 30-31).

This sentiment echoes that of an earlier writer. Cronbach (1975) states that "the special task of the social scientist in each generation is to pin down the contemporary facts. Beyond that, he shares with the humanistic scholar and the artist in the effort to gain insight into contemporary relationships" (p. 126).

Cronbach claims that statistical research is not able to take full account of the many interaction effects that take place in social settings. He gives examples of several empirical "laws" that do not hold true in actual settings to illustrate this point. Cronbach states that "the time has come to exorcise the null hypothesis," because it ignores effects that may be important, but that are not statistically significant (1975, p. 124). Qualitative inquiry accepts the complex and dynamic quality of the social world.

However, it is not necessary to pit these two paradigms against one another in a competing stance. Patton (1990) advocates a "paradigm of choices" that seeks "*methodological appropriateness* as the primary criterion for judging methodological quality." This will allow for a "situational responsiveness" that strict adherence to one paradigm or another will not (p. 39). Furthermore, some researchers believe that qualitative and quantitative research can be effectively combined in the same research project (Strauss and Corbin, 1990; Patton, 1990). For example, Russek and Weinberg (1993) claim that by using both quantitative and qualitative data, their study of technology-based materials for the elementary classroom gave insights that neither type of analysis could provide alone.

Basis for the Use of a Qualitative Methodology

There are several considerations when deciding to adopt a qualitative research methodology. Strauss and Corbin (1990) claim that qualitative methods can be used to better understand any phenomenon about which little is yet known. They can also be used to gain new perspectives on things about which much is already known, or to gain more in-depth information that may be difficult to convey quantitatively. Thus, qualitative methods are appropriate in situations where one needs to first identify the variables that might later be tested quantitatively, or where the researcher has determined that quantitative measures cannot adequately describe or interpret a situation. Research problems tend to be framed as open-ended questions that will support discovery of new information. Greene's 1994 study of women in the trades, for example, asked "What personal characteristics do tradeswomen have in common? In what way, if any, did role models contribute to women's choices to work in the trades?" (p. 524a).

The ability of qualitative data to more fully describe a phenomenon is an important consideration not only from the researcher's perspective, but from the reader's perspective as well. "If you want people to understand better than they otherwise might, provide them information in the form in which they usually experience it" (Lincoln and Guba, 1985, p. 120). Qualitative research reports, typically rich with detail and insights into participants' experiences of the world, "may be epistemologically in harmony with the reader's experience" (Stake, 1978, p. 5) and thus more meaningful.

Features of Qualitative Research

Several writers have identified what they consider to be the prominent characteristics of qualitative, or naturalistic, research (see, for example: Bogdan and Biklen, 1982; Lincoln and Guba, 1985; Patton, 1990; Eisner, 1991). The list that follows represents a synthesis of these authors' descriptions of qualitative research:

1. Qualitative research uses the natural setting as the source of data. The researcher attempts to observe, describe and interpret settings as they are, maintaining what Patton calls an "empathic neutrality" (1990, p. 55).
2. The researcher acts as the "human instrument" of data collection.
3. Qualitative researchers predominantly use inductive data analysis.
4. Qualitative research reports are descriptive, incorporating expressive language and the "presence of voice in the text" (Eisner, 1991, p. 36).
5. Qualitative research has an interpretive character, aimed at discovering the meaning events have for the individuals who experience them, and the interpretations of those meanings by the researcher.
6. Qualitative researchers pay attention to the idiosyncratic as well as the pervasive, seeking the uniqueness of each case.
7. Qualitative research has an emergent (as opposed to predetermined) design, and researchers focus on this emerging process as well as the outcomes or product of the research.
8. Qualitative research is judged using special criteria for trustworthiness (these will be discussed in some detail in a later section).

Patton (1990) points out that these are not "absolute characteristics of qualitative inquiry, but rather strategic ideals that provide a direction and a framework for developing specific designs and concrete data collection tactics" (p. 59). These characteristics are considered to be "interconnected" (Patton, 1990, p. 40) and "mutually reinforcing" (Lincoln and Guba, 1985, p. 39).

It is important to emphasize the emergent nature of qualitative research design. Because the researcher seeks to observe and interpret meanings in context, it is neither possible nor appropriate to finalize research strategies before data collection has begun (Patton, 1990). Qualitative research proposals should, however, specify primary questions to be explored and plans for data collection strategies.

The particular design of a qualitative study depends on the purpose of the inquiry, what information will be most useful, and what information will have the most credibility. There are no strict criteria for sample size (Patton, 1990). "Qualitative studies typically employ multiple forms of evidence.…[and] there is no statistical test of significance to determine if results 'count'" (Eisner, 1991, p. 39). Judgments about usefulness and credibility are left to the researcher and the reader.

The Role of the Researcher in Qualitative Inquiry

Before conducting a qualtitative study, a researcher must do three things. First, (s)he must adopt the stance suggested by the characteristics of the naturalist paradigm. Second, the researcher must develop the level of skill appropriate for a human instrument, or the vehicle through which data will be collected and interpreted. Finally, the researcher must prepare a research design that utilizes accepted strategies for naturalistic inquiry (Lincoln and Guba, 1985).

Glaser and Strauss (1967) and Strauss and Corbin (1990) refer to what they call the "theoretical sensitivity" of the researcher. This is a useful concept with which to evaluate a researcher's skill and readiness to attempt a qualitative inquiry.

> Theoretical sensitivity refers to a personal quality of the researcher. It indicates an awareness of the subtleties of meaning of data. …[It] refers to the attribute of having insight, the ability to give meaning to data, the capacity to understand, and capability to separate the pertinent from that which isn't (Strauss and Corbin, 1990, p. 42).

Strauss and Corbin believe that theoretical sensitivity comes from a number of sources, including professional literature, professional experiences, and personal experiences. The credibility of a qualitative research report relies heavily on the confidence readers have in the researcher's ability to be sensitive to the data and to make appropriate decisions in the field (Eisner, 1991; Patton, 1990).

Lincoln and Guba (1985) identify the characteristics that make humans the "instrument of choice" for naturalistic inquiry. Humans are responsive to environmental cues, and able to interact with the situation; they have the ability to collect information at multiple levels simultaneously; they are able to perceive situations holistically; they are able to process data as soon as they become available; they can provide immediate feedback and request verification of data; and they can explore atypical or unexpected responses.

Research Design and Data Collection Strategies

Eisner (1991) claims there is a "paucity of methodological prescriptions" for qualitative research, because such inquiry places a premium on the strengths of the researcher rather than on standardization (p. 169). Lincoln and Guba (1985) provide a fairly detailed outline for the design of naturalistic inquiry, which includes these general steps:

1. Determine a focus for the inquiry. This should establish a boundary for the study, and provide inclusion/exclusion criteria for new information. Boundaries, however, can be altered, and typically are.
2. Determine the fit of the research paradigm to the research focus. The researcher must compare the characteristics of the qualitative paradigm with the goals of the research.
3. Determine where and from whom data will be collected.
4. Determine what the successive phases of the inquiry will be. Phase one, for example, might feature open-ended data collection, while successive phases will be more focused.
5. Determine what additional instrumentation may be used, beyond the researcher as the human instrument.
6. Plan data collection and recording modes. This must include how detailed and specific research questions will be, and how faithfully data will be reproduced.
7. Plan which data analysis procedures will be used.
8. Plan the logistics of data collection, including scheduling and budgeting.
9. Plan the techniques that will be used to determine trustworthiness.

Steps one and two have been addressed in previous sections; the remaining steps will be addressed below.

Sampling Strategies for Qualitative Researchers

In quantitative inquiry, the dominant sampling strategy is probability sampling, which depends on the selection of a random and representative sample from the larger population. The purpose of probability sampling is subsequent generalization of the research findings to the population. By contrast, *purposeful sampling* is the dominant strategy in qualitative research. Purposeful sampling seeks information-rich cases which can be studied in depth (Patton, 1990).

Patton identifies and describes 16 types of purposeful sampling. These include: extreme or deviant case sampling; typical case sampling; maximum variation sampling; snowball or chain sampling; confirming or disconfirming case sampling; politically important case sampling; convenience sampling; and others (1990, pp. 169-183). According to Lincoln and Guba (1985), the most useful strategy for the naturalistic approach is maximum variation sampling. This strategy

> aims at capturing and describing the central themes or principal outcomes that cut across a great deal of participant or program variation. For small samples a great deal of heterogeneity can be a problem because individual cases are so different from each other. The maximum variation sampling strategy turns that apparent weakness into a strength by applying the following logic: Any common patterns that emerge from great variation are of particular interest and value in capturing the core experiences and central, shared aspects or impacts of a program (Patton, 1990, p. 172).

Maximum variation sampling can yield detailed descriptions of each case, in addition to identifying shared patterns that cut across cases. See Hoepfl (1994) for an illustration of this strategy applied to technology education research. Several examples of studies employing case sampling can also be found in the technology education literature (see Brown, 1995; Hansen, 1995; and Lewis, 1995 and 1997)

In spite of the apparent flexibility in purposeful sampling, researchers must be aware of three types of sampling error that can arise in qualitative research. The first relates to distortions caused by insufficient breadth in sampling; the second from distortions introduced by changes over time; and the third from distortions caused by lack of depth in data collection at each site (Patton, 1990).

Data Collection Techniques

The two prevailing forms of data collection associated with qualitative inquiry are interviews and observation.

Interviews

Qualitative interviews may be used either as the primary strategy for data collection, or in conjunction with observation, document analysis, or other techniques (Bogdan and Biklen, 1982). Qualitative interviewing utilizes open-ended questions that allow for individual variations. Patton (1990) writes about three types of qualitative interviewing: 1) informal, conversational interviews; 2) semi-structured interviews; and 3) standardized, open-ended interviews.

An interview guide or “schedule” is a list of questions or general topics that the interviewer wants to explore during each interview. Although it is prepared to insure that basically the same information is obtained from each person, there are no predetermined responses, and in semi-structured interviews the interviewer is free to probe and explore within these predetermined inquiry areas. Interview guides ensure good use of limited interview time; they make interviewing multiple subjects more systematic and comprehensive; and they help to keep interactions focused. In keeping with the flexible nature of qualitative research designs, interview guides can be modified over time to focus attention on areas of particular importance, or to exclude questions the researcher has found to be unproductive for the goals of the research (Lofland and Lofland, 1984).

Recording Data. A basic decision going into the interview process is how to record interview data. Whether one relies on written notes or a tape recorder appears to be largely a matter of personal preference. For instance, Patton says that a tape recorder is "indispensable" (1990, p. 348), while Lincoln and Guba "do not recommend recording except for unusual reasons" (1985, p. 241). Lincoln and Guba base their recommendation on the intrusiveness of recording devices and the possibility of technical failure. Recordings have the advantage of capturing data more faithfully than hurriedly written notes might, and can make it easier for the researcher to focus on the interview.

Observations

The classic form of data collection in naturalistic or field research is observation of participants in the context of a natural scene. Observational data are used for the purpose of description—of settings, activities, people, and the meanings of what is observed from the perspective of the participants. Observation can lead to deeper understandings than interviews alone, because it provides a knowledge of the context in which events occur, and may enable the researcher to see things that participants themselves are not aware of, or that they are unwilling to discuss (Patton, 1990). A skilled observer is one who is trained in the process of monitoring both verbal and nonverbal cues, and in the use of concrete, unambiguous, descriptive language. Sours' (1997) study of teaching and learning styles provides a good example of descriptive language applied to the technology classroom.

There are several observation strategies available. In some cases it may be possible and desirable for the researcher to watch from outside, without being observed. Another option is to maintain a passive presence, being as unobtrusive as possible and not interacting with participants. A third strategy is to engage in limited interaction, intervening only when further clarification of actions is needed. Or the researcher may exercise more active control over the observation, as in the case of a formal interview, to elicit specific types of information. Finally, the researcher may act as a full participant in the situation, with either a hidden or known identity. Each of these strategies has specific advantages, disadvantages and concerns which must be carefully examined by the researcher (Schatzman and Strauss, 1973).

The presence of an observer is likely to introduce a distortion of the natural scene which the researcher must be aware of, and work to minimize. Critical decisions, including the degree to which researcher identity and purposes will be revealed to participants, the length of time spent in the field, and specific observation techniques used, are wholly dependent on the unique set of questions and resources brought to each study. In any case, the researcher must consider the legal and ethical responsibilities associated with naturalistic observation.

Recording Data. Field researchers rely most heavily on the use of field notes, which are running descriptions of settings, people, activities, and sounds. Field notes may include drawings or maps. Acknowledging the difficulty of writing extensive field notes during an observation, Lofland and Lofland (1984) recommend jotting down notes that will serve as a memory aid when full field notes are constructed. This should happen as soon after observation as possible, preferably the same day. In addition to field notes, researchers may use photographs, videotapes, and audio tapes as means of accurately capturing a setting.

Gaining Access and Researcher Obligations

Based on their experience with naturalistic research, Lofland and Lofland (1984) believe that researchers are more likely to gain successful access to situations if they make use of contacts that can help remove barriers to entrance; if they avoid wasting respondents' time by doing advance research for information that is already part of the public record; and if they treat respondents with courtesy. Because naturalistic researchers are asking participants to "grant access to their lives, their minds, [and] their emotions," it is also important to provide respondents with a straightforward description of the goals of the research (p. 25).

Other Sources of Data

Another source of information that can be invaluable to qualitative researchers is analysis of documents. Such documents might include official records, letters, newspaper accounts, diaries, and reports, as well as the published data used in a review of literature. In his study of technology teachers in training, Hansen (1995) analyzed journal entries and memos written by participants, in addition to interviews. Hoepfl (1994), in her study of closure of technology teacher education programs, used newspaper reports, university policy documents, and department self-evaluation data, where available, to supplement data gained through interviews.

There are some specialized forms of qualitative research which rely solely on analysis of documents. For example, Gagel (1997) used a process known as *hermeneutic inquiry* to investigate the literature on both literacy and technology. Patton (1990) provides a good overview of the various theoretical orientations that inform the "rich menu of alternative possibilities within qualitative research" (p. 65).

Deciding When to Stop Sampling

Qualitative researchers have few strict guidelines for when to stop the data collection process. Criteria include: 1) exhaustion of resources; 2) emergence of regularities; and 3) overextension, or going too far beyond the boundaries of the research (Guba, 1978). The decision to stop sampling must take into account the research goals, the need to achieve depth through triangulation of data sources, and the possibility of greater breadth through examination of a variety of sampling sites.

Analysis of Data

Bogdan and Biklen define qualitative data analysis as "working with data, organizing it, breaking it into manageable units, synthesizing it, searching for patterns, discovering what is important and what is to be learned, and deciding what you will tell others" (1982, p. 145). Qualitative researchers tend to use inductive analysis of data, meaning that the critical themes emerge out of the data (Patton, 1990). Qualitative analysis requires some creativity, for the challenge is to place the raw data into logical, meaningful categories; to examine them in a holistic fashion; and to find a way to communicate this interpretation to others.

Sitting down to organize a pile of raw data can be a daunting task. It can involve literally hundreds of pages of interview transcripts, field notes and documents. The mechanics of handling large quantities of qualitative data can range from physically sorting and storing slips of paper to using one of the several computer software programs that have been designed to aid in this task (see Brown, 1996, for a description of one of these programs).

Analysis begins with identification of the themes emerging from the raw data, a process sometimes referred to as "open coding" (Strauss and Corbin, 1990). During open coding, the researcher must identify and tentatively name the conceptual categories into which the phenomena observed will be grouped. The goal is to create descriptive, multi-dimensional categories which form a preliminary framework for analysis. Words, phrases or events that appear to be similar can be grouped into the same category. These categories may be gradually modified or replaced during the subsequent stages of analysis that follow.

As the raw data are broken down into manageable chunks, the researcher must also devise an "audit trail"—that is, a scheme for identifying these data chunks according to their speaker and the context. The particular identifiers developed may or may not be used in the research report, but speakers are typically referred to in a manner that provides a sense of context (see, for example, Brown, 1996; Duffee and Aikenhead, 1992; and Sours, 1997). Qualititative research reports are characterized by the use of "voice" in the text; that is, participant quotes that illustrate the themes being described.

The next stage of analysis involves re-examination of the categories identified to determine how they are linked, a complex process sometimes called "axial coding" (Strauss and Corbin, 1990). The discrete categories identified in open coding are compared and combined in new ways as the researcher begins to assemble the "big picture." The purpose of coding is to not only describe but, more importantly, to acquire new understanding of a phenomenon of interest. Therefore, causal events contributing to the phenomenon; descriptive details of the phenomenon itself; and the ramifications of the phenomenon under study must all be identified and explored. During axial coding the researcher is responsible for building a conceptual model and for determining whether sufficient data exists to support that interpretation.

Finally, the researcher must translate the conceptual model into the story line that will be read by others. Ideally, the research report will be a rich, tightly woven account that "closely approximates the reality it represents" (Strauss and Corbin, 1990, p. 57). Many of the concerns surrounding the presentation of qualitative research reports are discussed in the section "Judging Qualitative Research" which follows.

Although the stages of analysis are described here in a linear fashion, in practice they may occur simultaneously and repeatedly. During axial coding the researcher may determine that the initial categories identified must be revised, leading to re-examination of the raw data. Additional data collection may occur at any point if the researcher uncovers gaps in the data. In fact, informal analysis begins with data collection, and can and should guide subsequent data collection. For a more detailed yet very understandable description of the analysis process, see Simpson and Tuson (1995).

The Product of Qualitative Data Analysis

In their classic text *Discovery of Grounded Theory*, Glaser and Strauss (1967) describe what they believe to be the primary goal of qualitative research: the generation of theory, rather than theory testing or mere description. According to this view, theory is not a "perfected product" but an "ever-developing entity" or process (p. 32). Glaser and Strauss claim that one of the requisite properties of grounded theory is that it be "sufficiently general to be applicable to a multitude of diverse situations within the substantive area" (p. 237).

The grounded theory approach described by Glaser and Strauss represents a somewhat extreme form of naturalistic inquiry. It is not necessary to insist that the product of qualitative inquiry be a theory that will apply to a "multitude of diverse situations." Examples of a more flexible approach to qualitative inquiry can be gained from a number of sources. For example, both Patton (1990) and Guba (1978) state, in the same words, that "naturalistic inquiry is always a matter of degree" of the extent to which the researcher influences responses and imposes categories on the data. The more "pure" the naturalistic inquiry, the less reduction of data into categories.

Figure 1 illustrates one interpretation of the relationship between description, verification, and generation of theory—or, in this case, the development of what Cronbach (1975) calls "working hypotheses," which suggests a more tractable form of analysis than the word "theory." According to this interpretation, a researcher may move between points on the description/verification continuum during analysis, but the final product will fall on one particular point, depending on the degree to which it is naturalistic.

Figure 1. Description, verification and generation of working hypotheses in qualitative research.

In keeping with a naturalistic stance, the researcher might conclude that, to the extent that findings are based on information from a variety of diverse situations, they *may* be applicable to a larger substantive area. However, their applicability to a particular situation is wholly dependent upon the conditions of the situation and the usefulness of the research findings to individual readers.

Judging Qualitative Research

The Role of the Reader

Those who are in a position to judge or use the findings of a qualitative inquiry must play a different type of role than people who review quantitative research. This is because "there are no operationally defined truth tests to apply to qualitative research" (Eisner, 1991, p. 53). Instead, researcher and readers "share a joint responsibility" for establishing the value of the qualitative research product (Glaser and Strauss, 1967, p. 232). "Pragmatic validation [of qualitative research] means that the perspective presented is judged by its relevance to and use by those to whom it is presented: *their* perspective and actions joined to the [researcher's] perspective and actions" (Patton, 1990, p. 485).

Eisner (1991) believes that the following three features of qualitative research should be considered by reviewers:

> *Coherence*: Does the story make sense? How have the conclusions been supported? To what extent have multiple data sources been used to give credence to the interpretation that has been made? (p. 53).

Related to coherence is the notion of "structural corroboration," also known as triangulation (p. 55).

> *Consensus*: The condition in which the readers of a work concur that the findings and/or interpretations reported by the investigator are consistent with their own experience or with the evidence presented (p. 56).

Finally, reviewers must assess the report's:

> *Instrumental Utility*: The most important test of any qualitative study is its usefulness. A good qualitative study can help us understand a situation that would otherwise be enigmatic or confusing (p. 58).

A good study can help us anticipate the future, not in the predictive sense of the word, but as a kind of road map or guide. "Guides call our attention to aspects of the situation or place we might otherwise miss" (Eisner, 1991, p. 59).

Addressing Trustworthiness in Qualitative Research

The basic question addressed by the notion of trustworthiness, according to Lincoln and Guba, is simple: "How can an inquirer persuade his or her audiences that the research findings of an inquiry are worth paying attention to?" (1985, p. 290). When judging qualitative work, Strauss and Corbin (1990) believe that the "usual canons of 'good science'…require redefinition in order to fit the realities of qualitative research" (p. 250). Lincoln and Guba (1985,

p. 300) have identified one alternative set of criteria that correspond to those typically employed to judge quantitative work (see Table 1).

Table 1
Comparison of criteria for judging the quality of quantitative versus qualitative research

Conventional terms	Naturalistic terms
internal validity	credibility
external validity	transferability
reliability	dependability
objectivity	confirmability

Smith and Heshusius (1986) sharply criticize those writers, like Lincoln and Guba, who they believe have adopted a stance of “detente” with rationalists. They are particularly incensed by Lincoln and Guba’s use of “comparable criteria,” which to their eyes look little different than the conventional criteria they supposedly replace. In either case, there must be a “belief in the assumption that what is known—be it an existent reality or an interpreted reality—stands independent of the inquirer and can be described without distortion by the inquirer” (p. 6). Smith and Heshusius claim that naturalistic research can offer only an “interpretation of the interpretations of others,” and that to assume an independent reality is “unacceptable” for the qualitative researcher (p. 9).

Their stance is a strong one, because the only reality it accepts is a completely mind-dependent one, which will vary from individual to individual; in other words, for Smith and Heshusius, there is no “out there” out there. For these researchers, it would not be possible to choose a best interpretation from among the many available, because no technique or interpretation can be “epistemologically privileged” (p. 9). To maintain this stance would seem to negate the value of doing research at all, because it prohibits the possibility of reconciling alternative interpretations.

Therefore, it is important to determine which criteria are consistent with the naturalistic paradigm, yet which allow for a declaration that “good science” has been carried out. In the following sections, conventional and naturalistic criteria will be discussed, with the goal of selecting criteria which are appropriate for judging the overall trustworthiness of a qualitative study.

Internal Validity versus Credibility

In conventional inquiry, internal validity refers to the extent to which the findings accurately describe reality. Lincoln and Guba (1985) state that “the determination of such isomorphism is in principle impossible” (p. 294), because one would have to know the “precise nature of that reality” and, if one knew this already, there would be no need to test it (p. 295). The conventional researcher must postulate relationships and then test them; the postulate cannot be proved, but only falsified. The naturalistic researcher, on the other hand, assumes the presence of multiple realities and attempts to represent these multiple realities adequately. Credibility becomes the test for this.

Credibility depends less on sample size than on the richness of the information gathered and on the analytical abilities of the researcher (Patton, 1990). It can be enhanced through triangulation of data. Patton identifies four types of triangulation: 1) methods triangulation; 2) data triangulation; 3) triangulation through multiple analysts; and 4) theory triangulation. Other techniques for addressing credibility include making segments of the raw data available for others to analyze, and the use of “member checks,” in which respondents are asked to corroborate findings (Lincoln and Guba, 1985, pp. 313-316).

External Validity / Generalizability versus Transferability

In conventional research, external validity refers to the ability to generalize findings across different settings. Making generalizations involves a trade-off between internal and external validity (Lincoln and Guba, 1985). That is, in order to make generalizable statements that apply to many contexts, one can include only limited aspects of each local context.

Lincoln and Guba (1985) admit that generalizability is “an appealing concept,” because it allows a semblance of prediction and control over situations (pp. 110-111). Yet they suggest that the existence of local conditions “makes it impossible to generalize” (p. 124). Cronbach (1975) discusses the problem by saying:

> The trouble, as I see it, is that we cannot store up generalizations and constructs for ultimate assembly into a network. It is as if we needed a gross of dry cells to power an engine and could only make one a month. The energy would leak out of the first cells before we had half the battery completed (p. 123).

According to Cronbach, “when we give proper weight to local conditions, any generalization is a working hypothesis, not a conclusion” (p. 125).

In the naturalistic paradigm, the *transferability* of a working hypothesis to other situations depends on the degree of similarity between the original situation and the situation to which it is transferred. The researcher cannot specify the transferability of findings; he or she can only provide sufficient information that can then be used by the reader to determine whether the findings are applicable to the new situation (Lincoln and Guba, 1985). Other writers use similar language to describe transferability, if not the word itself. For example, Stake (1978) refers to what he calls “naturalistic generalization” (p. 6). Patton suggests that “extrapolation” is an appropriate term for this process (1990, p. 489). Eisner says it is a form of “retrospective generalization” that can allow us to understand our past (and future) experiences in a new way (1991, p. 205).

Reliability versus Dependability

Kirk and Miller (1986) identify three types of reliability referred to in conventional research, which relate to: 1) the degree to which a measurement, given repeatedly, remains the same; 2) the stability of a measurement over time;

and 3) the similarity of measurements within a given time period (pp. 41-42). They note that “issues of reliability have received little attention” from qualitative researchers, who have instead focused on achieving greater validity in their work (p. 42). Although they give several examples of how reliability might be viewed in qualitative work, the essence of these examples can be summed up in the following statement by Lincoln and Guba (1985): “Since there can be no validity without reliability (and thus no credibility without dependability), a demonstration of the former is sufficient to establish the latter” (p. 316).

Nevertheless, Lincoln and Guba do propose one measure which might enhance the dependability of qualitative research. That is the use of an “inquiry audit,” in which reviewers examine both the process and the product of the research for consistency (1985, p. 317).

Objectivity versus Confirmability

Conventional wisdom says that research which relies on quantitative measures to define a situation is relatively value-free, and therefore objective. Qualitative research, which relies on interpretations and is admittedly value-bound, is considered to be subjective. In the world of conventional research, subjectivity leads to results that are both unreliable and invalid. There are many researchers, however, who call into question the true objectivity of statistical measures and, indeed, the possibility of ever attaining pure objectivity at all (Lincoln and Guba, 1985; Eisner, 1991).

Patton (1990) believes that the terms objectivity and subjectivity have become “ideological ammunition in the paradigms debate.” He prefers to “avoid using either word and to stay out of futile debates about subjectivity *versus* objectivity.” Instead, he strives for “empathic neutrality” (p. 55). While admitting that these two words appear to be contradictory, Patton points out that empathy “is a stance toward the people one encounters, while neutrality is a stance toward the findings” (p. 58). A researcher who is neutral tries to be non-judgmental, and strives to report what is found in a balanced way.

Lincoln and Guba (1985) choose to speak of the “confirmability” of the research. In a sense, they refer to the degree to which the researcher can demonstrate the neutrality of the research interpretations, through a “confirmability audit.” This means providing an audit trail consisting of 1) raw data; 2) analysis notes; 3) reconstruction and synthesis products; 4) process notes; 5) personal notes; and 6) preliminary developmental information (pp. 320 -321).

With regard to objectivity in qualitative research, it may be useful to turn to Phillips (1990), who questions whether there is really much difference between quantitative and qualitative research:

> Bad work of either kind is equally to be deplored; and good work of either kind is still—at best—only tentative. But the good work in both cases will be objective, in the sense that it has been opened up to criticism, and the reasons and evidence offered in both cases will have withstood serious scrutiny. The works will have faced potential refutation, and insofar as

they have survived, they will be regarded as worthy of further investigation (p. 35).

Discussion and Conclusion

The increased interest in qualitative research in recent years warrants a basic understanding of this paradigm on the part of all technology education researchers. This overview of qualitative research methods and issues represents a starting point only for those who are interested in using and/or reviewing qualitative research. Readers can choose from a growing body of literature on the topic for further guidance.

The decision to use qualitative methodologies should be considered carefully; by its very nature, qualitative research can be emotionally taxing and extraordinarily time consuming. At the same time, it can yield rich information not obtainable through statistical sampling techniques.

In the past, graduate students contemplating the use of qualitative inquiry were told that they would have to "sell" the idea to members of their research committees, who would probably view qualitative research as inferior to quantitative research. Fortunately, in most universities that belief has changed, to the point where qualitative research is the paradigm of choice in some schools. In spite of this growing acceptance, new researchers may still encounter difficulties in finding faculty advisors who are skilled in this type of research.

Qualitative researchers have a special responsibility to their subjects and their readers. Since there are no statistical tests for significance in qualitative studies, the researcher bears the burden of discovering and interpreting the importance of what is observed, and of establishing a plausible connection between what is observed and the conclusions drawn in the research report. To do all of this skillfully requires a solid understanding of the research paradigm and, ideally, guided practice in the use of qualitative observation and analysis techniques.

There are many useful research designs, the selection of which depends on the research questions being asked. Most importantly, technology educators must rise to the challenge to find and use rigorous, appropriate research techniques that address the significant questions facing the field.

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Upgrading Technology Towards the Status of a High School Matriculation Subject: A Case Study

Igor M. Verner, Shlomo Waks and Eli Kolberg

Introduction

Technological education in high schools is undergoing reform in relation to its status, goals and teaching/learning strategies. This trend is an important part of the worldwide general reform process aiming to make school education more meaningful, intellectual and creative. Real world problems, interdisciplinary approaches, project oriented learning, team cooperation and authentic assessment have become the highlights of recent curriculum innovations.

Curriculum design in technology, to a greater extent than in many other disciplines, calls for a variety of social, economic, historic-cultural and psychological considerations in addition to pedagogical factors (Waks, 1995). Diverse situations in different countries have led to the development of various models of technology education. A comparative study of approaches to teaching technology in England, France and the United States (Gradwell, 1996) indicates that differences originate in the history of the nations. Lewis (1996) compared technology education systems in the U. S. and U. K. and pointed out that there is great value in discussion and comparison of the different educational approaches among nations. He called for a cross-national comparison of case studies of specific technology programs "that can aid in constructing a grammar for communicating about the subject across cultures."

Technology education programs in Israel are of interest to technology educators, particularly since the Jerusalem International Science and Technology Education Conference (JISTEC '96). This article was prepared in response to a call for papers from the editor of JTE and presents one of the case studies mentioned at the conference.

Description of the Case Study Context

Technology is not a compulsory school subject in Israel. Post-primary schooling has two stages: the intermediate (junior high) school, grades 7-9, and the secondary (senior high) school, grades 10-12.

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Technology was not a junior high school subject until the national program "Tomorrow 98" was started (Ministry of Education, 1994) and the curriculum of a new integrated subject "Science and technology for intermediate schools" was published in 1996. New instructional methods and materials are being developed nationwide with a growing number of schools participating in the implementation of the new school subject.

Education in senior high schools is free, but is not compulsory beyond grade 10. It is subdivided into the general, technological, vocational (craft) and religious education trends. The first two trends lead the majority of students to a matriculation certificate while the last two lend to a certificate of completion.

Technological education in Israel is an advanced system having its historic roots in Zionist immigration and settling in former Palestine. Today technological schools provide education to approximately half of all secondary school students. Until the early seventies most of the technology schools were vocational oriented. Then the necessity to deepen the theoretical background of the graduates was recognized. Technological education evolved gradually by incorporating scientific and general subjects and currently includes a number of programs for specialization in computers, electronics, machinery, agriculture and other subjects. A list of courses selected from a specific technical college curriculum (first two year studies) is offered in each program. Many technology schools are associated with technical colleges.

The present curriculum of the general high school, which is the most popular trend in secondary education, does not include technology studies, except for fragmentary illustrations of the application of science. This situation is currently being revised, and several models for incorporating technology into general education, as a separate subject or part of an integrated science-technology curriculum, are being examined. Technology educators, involved in the examination process, believe that in any case, a systematic technology course accessible to any interested student should be offered (LaPorte and Sanders, 1995; de Vries, 1996).

It is reasonable to assume that approaches accepted in a technology education school, can not be directly adopted in a general high school. Existing narrow professional tendencies need to be reconsidered. Some expected directions of such a revision are discussed below.

Technology is an interdisciplinary subject. Basic knowledge in computers, electronics and machinery are essential to the same extent as is knowledge in physics, biology and history. Therefore general high schools are interested in a technology course which provides graduates with a polytechnic background.

The importance of technology studies for training hands-on and practical thinking skills is recognized, but revision is required in order to impart a more general value to these studies so as to prepare students for varied practical activities.

The acquisition of practical experience and a polytechnic background through the performance of creative tasks of design and construction is expected to become a stimulating factor in the study of technology in the general secondary school, as opposed to learning a profession as motivation in the technology education school. Therefore the emphasis on project oriented learning and technological problem solving in the general school course is anticipated. The course is expected to be optional, offering a basic level as well as advanced studies.

Some of the expected revisions required for the adoption of technology in a general high school, have become part of the new standards in technology education (Frantz, Gregson, Friedenberg, Walter and Miller, 1996). This reflects a reciprocal tendency the technological and general trends.

The Case Study Framework

One of the possible approaches to designing and implementing an advanced technology course in a general high school is proposed and discussed in this paper. The pilot optional course "An Introduction to Robotics and Real Time Control" presents a two-year program, which includes theoretical studies, lab experiments and construction work, as well as a practical mini-project and a theoretical mini-research.

The program started in 1994 at the Ohel-Shem general high-school (School #1). Blich school (School #2) has joined since 1995, and an additional school associated with the Hebrew University (School #3) joined in 1996. By the 1996-97 school year a total of 122 students (grades 10-12) had participated in the program: 17 students in 1994-96, 43 in 1995-97, 62 students started in 1996 (see the 3 dimensional graphic description in Fig. 1).

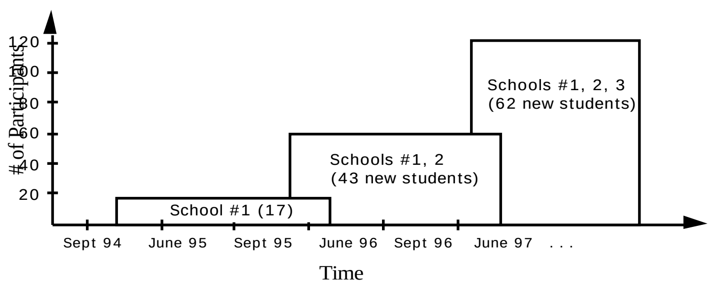

Figure 1. Participation of high schools in the program.

The program is currently authorized by the Israel Ministry of Education to be used as a substitute of the conventional course "Machine Control" which is a part of the technology (machinery) program. The course grade accepted by the general high school student is included in the advanced disciplines section of the matriculation certificate under the title "Machine Control." It provides the graduate with a considerable bonus when applying for engineering university studies.

The three schools, in which the program has been implemented so far, are known as top-level general secondary schools. Participants were students studying math and physics at the advanced level, who had not studied technology at school beforehand and had joined the course voluntarily. A few of them, prior to the course, had participated in extracurricular youth activities in computers or electronics. All of those who started the program finished it successfully. The students' graduation project reports passed external inspection and evaluation at the Israel Ministry of Education (Dept. of Science and Technology). The ministry currently recommends the wider implementation of the program. Teacher training courses for the program have been conducted since October 1996.

In this paper the course curriculum and it's implementation are discussed in relation to the following questions:

1. To what extent can a free choice technology course be attractive for general high school students?
2. What should be the central course objective?
3. What teaching methods are most relevant?
4. What changes in students' perceptions and behavior may be stimulated by the course?

It should be noted that the principles of design of an interdisciplinary robotics course, which were implemented in the program, were assessed in our former research on training spatial ability through manipulating robot movements (Waks and Verner, 1993; Waks and Verner, 1997).

The Course Curriculum

The course includes basic studies of electronics, computers, mechanics, control and design in the robot system context. When performing practical mini projects the students are involved in constructing hardware components and developing software modules for the robot system, while their theoretical mini research assignments focus on investigating technology problems. We will use the following technical abbreviations:

DC - Direct Current,
PWM - Pulse Width Modulation,
PFM - Pulse Frequency Modulation,
RS-232 - Recommended Standard number 232,
I/O - Input/Output,
PCB - Printed Circuit Board.

The curriculum for "An Introduction to Robotics and Real-Time Control" is given in Table 1. The main subjects taught and their sub-topics mentioned in Table 1 are detailed below.

Electronics studies include definitions of voltage, current and resistance, Ohm's and Kirchhoff's laws, DC circuits and components, H-bridge circuit, PWM and PFM.

Computer studies focus on the basics of binary logic and Boolean algebra, logic gates, Karnaugh maps, computer structure and its functioning, address bus, data bus and control bus, RS-232 serial communication. While studying the subject, the students build an electronic board for further use as a base for the robot controller.

The *Assembly language* subject includes computer components interface and addressing modes, commands and instructions for I/O, interrupts and communication. As a part of their studies, students program internal functions of the robot controller, as well as processes of robot motion and interaction.

Table 1
Course curriculum

Learning Contents and Activities	Learning hours
Electronics	
Fundamental concepts and electronic circuits	4
Components and integrated circuits	6
Digital electronics	15
Motor control circuits	5
Computer	
Logic and Boolean algebra	6
Computer components	14
Serial communication, address, data and control buses	5
Assembly language and robot programming	
Microprocessor structure and addressing modes	5
Assembly language instructions and commands, interpreter, "high language" application	16
Input/output, interrupts and communication implementation	9
Robot control	10
Mechanics	
Materials, forces and torque	5
Motors and gears	10
Control	
Control types	7
Motor control	5
Robot movement closed loop control	8
Robotics	
Robot design considerations	9
Integrating hardware and software for emergency situations escape	6
Sensor's types	5
Laboratory	
Electronic PCB construction	12
Designing and building a robot	23
Final tests, troubleshooting, debugging and fixing	5
Creative projects	
Practical mini project	40
Theoretical mini research	80

The *Mechanics* chapter deals with materials, forces and torques, robot frame and motor shaft loading, DC servo and stepping motors. Design of the robot body and its construction by means of heat folding sawing and drilling machines are part of the study.

The *Control* section relates to open and closed loop modes, DC motor and stepping motor position and speed control, robot motion and collision avoidance.

The *Robotics* study is focused on factors influencing robot design such as weight, stability, loads, collision recovery and functionality. In addition to general factors, specific requirements are considered for providing applications of basic robot configuration for implementing different tasks. These factors are motor selection and reevaluation of loads, emergency situation escape and sensor feedback configuration.

Laboratory workshops include PCB construction, building the designed robot system, testing, troubleshooting and fixing.

Creative projects provide students with the challenge of self-supporting theoretical and practical activities. Team tasks assigned for the practical mini project relate to adapting and extending the robot for executing various assignments in an automated mode. These assignments may be vacuum cleaning, dynamic video monitoring, transporting and manipulating objects. The purpose of individual theoretical mini research-work is to investigate some specific problems arising in technology that are not necessarily associated with the mini project. Two examples of such activities are a sensor-based method for avoiding robot collisions, and the implementation of voice recognition for robot control.

Learning Strategy

Our learning strategy is compatible with the framework of an optional course, in which students meet technology for the first time. It is therefore based on:

- streamlining learning through pragmatic activities;
- concentrating on studies of modern technology basics, operating technological systems and design activities;
- attracting students towards technology issues through diverse theoretical, hands-on and creative team-tasks; and
- providing students with opportunities to apply and evaluate knowledge and methods acquired in mathematics and science.

Special attention is paid to an introductory talk with potentially interested students, which is aimed at presenting the proposed technology course in an attractive way. The rationale, curriculum and benefits of the course are specified, together with displaying practical learning activities and demonstrating robot systems developed by former students. Our three-year experience and student feedback indicate the importance and influence of this educational strategy.

The course schedule, provides for weekly 4-hours workshops and is a suitable setting for attracting students to technology. The parallel study of several different subjects at each workshop, instead of a single disciplinary subject-by-subject approach, provides students with diverse learning activities as well as tasks of design and construction. Table 2 presents a typical timetable of the first year workshops.

Table 2
A typical time-table for a weekly meeting

Hour	Learning topic
1st	Electronics and mechanics hardware
2nd	Computers and control
3rd	Assembly language (experimenting using development system)
4th	Robot construction

Second year studies concentrate on the performance of creative tasks, while applying a learning and assessment strategy based on student portfolios (Shackelford, 1996). Practical Mini Project and Theoretical Mini Research are carried out in parallel. Combined, they provide students with relatively broad experiences in technology. Table 3 summarizes the main features of our approach to learning through projects.

Example

As an example, we will consider the issue of a DC-motor speed control. In particular, students learn to produce a process of 4-stepped speed control for a set-up of DC motors.

The method of direct potentiometer-based voltage control, which is familiar to students from the physics course, does not provide an appropriate solution. The idea is to use pulse width modulation (PWM) for speed control.

While learning the subject, students become familiar with the principles of wave superposition. At the next stage, they acquire the preliminary experience of applying the PWM method through practice with the microprocessor control instructional module.

PWM and other methods of microprocessor control, are learned in three stages:

- theoretical studies;
- experience with microprocessor control instructional module (MCIM);
- practice in robot motion control.

MCIM is an instructional package including hardware and software components we developed in order to simulate the process of peripheral device control. It is connected to a computer through a RS-232 serial communication port for program downloading and debugging, and the peripherals are connected to the module parallel ports.

Students program processes that control variable speed in assembly language, examine and verify operation using MCIM and apply their experience to real robot motion control in the mini project framework.

Table 3
Goals and activities of the creative projects

Features	Practical Mini Project	Theoretical Mini Research
Didactic goals	Practical problem solving	Qualitative reasoning and research practice (inf. id. & analysis)
The assignment	Design, build and program a robot configuration for automatic execution of some specific tasks	Investigation of an actual problem that can arise in technology
Performers	Teams of 2-3 students	Individuals
Portfolio products	Robot configuration models made by student teams	Individual (written) research reports
Assessment in class	Functional demonstration of the robot-model	Oral presentation
Learning activities:	Defining the outcome Work planning Constructing the robot set-up Functional operating the outcome	Problem definition Bibliographic search Subject matter studies & functional analysis Findings interpretation

Students' Attitudes

The style of our course differs from that of the conventional high school studies in several dimensions:

- optional vs. obligatory;
- portfolio evaluation vs. exam procedure;
- technology dominant and interdisciplinary vs. purely scientific and disciplinary;
- practical, purposeful vs. theoretical, general;
- creative individual and team tasks vs. routine exercises binding for all;
- focus on application, analysis and synthesis activities vs. remembering and understanding emphasis.

In these features the course is similar to some cross-disciplinary engineering courses (Rahn, Dawson and Paul, 1995); however, it remains an introductory technology course for beginners.

For high school students participating in the course, the proposed learning strategy was as new as the learning subject. As a result it was decided to use a questionnaire, in which we asked students for their opinions about the course.

The questionnaire was presented at the beginning of the 1996-97 school year to 43 students from two high schools, that had finished their practical mini-projects and started second year studies. In addition to this, personal interviews were conducted with six out of 17 graduates of the 1994-96 program. In this article we will discuss initial findings regarding students' attitudes towards the course and the subject.

Attitudes Towards the Course

The mean grade that students gave to the course was 80 (out of 100). High average grades were also assigned to the course creativity (88.4) and importance of the acquired technology knowledge background (83.7). High correlation of the individual grades for these three categories was indicated. The Pearson correlation and significance coefficients are given in Table 4, where the categories of grades are nominated as Creativity, Technology and Course-score variables.

Table 4
Correlation of creativity, technology and course-score

		Creativity	Technology	Course-score
Pearson Correlation	Creativity	1.000	.424	.573
	Technology	.424	1.000	.527
	Course-score	.573	.527	1.000
Significance	Creativity		.005	.000
	Technology	.005		.000
	Course-score	.000	.000	

Dependence of the course grade on the grades received in course creativity and acquired technology knowledge was determined. As may be seen from Table 5 the multiple R of the Course-score against the cumulative affect of Technology and Creativity variables is very significant. Specifically 42.6% of the Course-score differences may be explained by diversity of subjective attitudes towards *both* Technology and Creativity. A linear stepwise regression was performed in order to analyze the contribution of each variable. Results presented in Table 6 indicate that 32.8% ($R^2 = 0.328$) of differences in Course-score may be explained by *separate* effects of the Creativity variable. The "contribution" of the Technology variable to the explanation of Course-score differences, while entered into the predictive equation as a second variable, is 0.098 ($\Delta = 0.426 - 0.328 = 0.098$).

Table 5
Dependence of Course-score on both technology and creativity

Variables			
Entered	Removed	*R*	R^2
Technology, Creativity	None	.653	.426

Table 6
Dependence of Course-score on technology or creativity

Variables			
Entered	Removed	*R*	R^2
Creativity	None	.573	.328
Technology		.653	.426

In addition to aspects of attitudes towards the course discussed above, attitudes towards the learning strategy components were also examined. Concerning the importance of cross-disciplinary links created in the course, many students noted that background knowledge in mathematics (72%) and physics (93%) were meaningful.

Students pointed out that team cooperation with the classmates was important, especially while working on practical mini-projects. High correlation between individual contribution to team success and personal benefit derived from team cooperation, was indicated.

Attitude Towards Technology

Most of the respondents (88.4%) pointed out that before the course, they had lacked any technological background, except for some computer handling skills. For a considerable part of students (18.6%) technology evoked only feelings of fear. The responses point to a significant change of students' attitude towards technology at the end of the course. Most of the graduates (86.0%) believe that they may make a successful career in technology; many of them (77.5%) plan to major in engineering.

Some of the students interviewed revealed that they had been quite affected by the new subject as well as the new teaching methods used in the course. They stated that owing to the course, they had changed their point of view about technology. The respondents mentioned that they had become interested in technological systems, were more confident in operating technical devices, and that this had resulted in more reflection as to the implementation of some of their own ideas.

Conclusions

The view that systematic technology studies are a prerogative of vocational education should be revised. Our case study shows that there is a valid alternative (but not a substitute) - Technology as a matriculation subject in high school. We believe that the option to learn Technology at the matriculation level should be accessible to any interested high school student.

Robotics presents one appropriate interdisciplinary frame for learning basics of mechanics, electronics, programming and control. Our experience of development, implementation and evaluation in the course "Introduction to Robotics and Real Time Control" indicates that a two-year 310 hours extent studies enable covering the proposed curriculum. The first year program (190 hours) is dedicated to diverse theoretical and hands-on studies of modern technology basics, creative design and construction activities. The second year (120 hours) is focused on performing practical mini-project and theoretical mini-research.

The course is conducted in high schools under supervision of the Israeli Ministry of Education, including inspection and evaluation of student portfolios. High average grades (92) were assigned to 1995-96 graduates. The grades were included in the matriculation certificates under the title "Machine control." Universities provide graduates with a considerable bonus due to their matriculation when applying for engineering studies. Defense forces direct them to technical service positions.

The case study results provide some grounding in support of the following answers to the four research questions related to the course curriculum and it's implementation.

1. The technology education program has been offered in general high schools since 1994 on a free choice basis. Throughout this period there was an increase in the number of schools and students participating in the program, some applicants have even been rejected. All students who started the course in 1994 and in 1995 finished their studies successfully. The students assigned high average grades to the course and to their own benefits from it.
2. Objectives stimulating development of creativity, hands-on and practical thinking skills as well as acquisition of a polytechnic background were central in the course. The dominating role of these factors in students' attitude towards the course was indicated.
3. In the first year the course was conducted in the form of weekly workshops, where several subjects were studied in parallel through diverse theoretical and hands-on activities, including design and construction team-tasks. Second year studies focused on the performance of creative tasks (a practical mini project and a theoretical mini research), while applying a learning and assessment strategy of student portfolios. We believe that such a combination of workshops and creative projects is relevant and important for achieving the course goals.
4. A significant change of students' attitudes towards technology was indicated, as a result of participating in the program. Prior to the course most of the students lacked any technological background and even awareness. At the end of the course most of the students believed that they may make a successful career in technology, and many of them decided to major in engineering. Students interviewed mentioned that

they had become interested in technological systems and more confident in operating technical devices. They appreciated the experience of teamwork cooperation acquired in the course.

The main conclusions of the article are valid only to the specific circumstances and conditions of the case study. Further research has to be carried out in other cases before general conclusions can be drawn.

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Book Review

Black, Paul & Atkin, J. Myron (Eds.). (1996). ***Changing the subject: Innovations in science, mathematics and technology education*****. Routledge, $18.95 (paperback), 230 pp. (ISBN 0-415-14623-2)**

Reviewed by Ann Marie Hill and Gary Hepburn

Changing the Subject: Innovations in Science, Mathematics and Technology Education, edited by Paul P. Black and J. Myron Atkin, is one of the latest in the genre of Mathematics, Science and Technology (MST) publications. The book was sponsored by the Organization for Economic Co-operation and Development's (OECD) Center for Educational Research and Innovation (CERI). The content of the book draws on 23 case studies from 13 different countries. Most of the studies concentrate on one of the three subject areas: nine focus on science education; seven on mathematics education, and two on technology education. One of the mathematics education studies deals with the use of computers for instruction. The remainder of the studies involve integrating subject areas, with four studies focusing on science and mathematics education and the remaining study on science, mathematics, and technology education. The age range of the students in the various case studies is from 4 to 19 years. Some of the case studies had a very narrow age range (e.g., 13 to 14 years) while others were more diverse (e.g., for example, 5 to 18 years). These and other details for each case study are documented in an Appendix titled, *Summaries of the 23 case studies*. Readers need to familiarize themselves with the summaries to contextualize the reporting throughout the book.

The first part of the book title, *Changing the Subject*, has several possible interpretations. The subject to be changed could be education in general or it could be the subject areas of science, mathematics, and technology, either as individual subjects or as MST, an integrated subject. The book title could also consider students or teachers as the subjects that are to be changed. Although reading the book does little to indicate which interpretations the editors of the volume have in mind, there may be some value in the ambiguity of the title as each of the possible interpretations represents an important facet of a complex task. The second part of the title, *Innovations in Science, Mathematics and Technology Education*, is indeed indicative of the various foci of the text. While the book does deal with each of the three designated subjects, it is predominantly about *science*. Mathematics receives somewhat less attention than science, and technology ends up with an even lesser profile.

Reporting in Science, Mathematics and Technology Education

Chapter 2 is primarily concerned with changing conceptions of science and mathematics, with an emphasis on science. Little reference is made to technology education. When mentioned, technology is frequently depicted as computers. An example of such a reference is, “Students use contemporary technology and, especially, learn its power to gather and manipulate data more efficiently” (p. 38). The summary below provides a sense of the dialogue throughout the book with respect to the three subjects.

Science

The reporting on science education depicts a movement from a transmissive model towards a constructivist view of learning by attending to students’ prior conceptions and recognizing that students are active constructors of their own knowledge. Here science is used to achieve general learning outcomes involving the development of intellectual and social skills. The authors see these changes moving science education from a “purist” view of science towards one that appreciates “science in action” which consists of “real and messy everyday problems.” The authors state that, “Students’ scientific work also involves practical activity, collaboration in thoughtful investigation which has to confront hard evidence, and the problems of their personal and social lives” (p. 88).

Mathematics

Descriptions of changes in mathematics education are presented as being much like changes in science in the sense that new collaborative, team approaches are being used. Reported on as well is a move from “pure” to “applied” where a greater relation of real problems from the world outside the school has increased student motivation. The authors document the use of educational technology, e.g. calculators, as important in the transformation of mathematics education.

Technology Education

While technology has perhaps the longest history of the three subjects that are the focus of the book, it is largely depicted as a subject without a history. It is seen only as a newcomer relative to science and mathematics. Technology is not examined in its own historical context or in the same detail as science and mathematics. In the absence of a more developed history and description, it is difficult to assess the validity of some of the claims that the authors make concerning technology education. For example, the authors claim that although technology education has always been founded in practical activities, these activities have not always been based on real world contexts. In addition they claim that there is a movement towards greater “theoretical reflection about the nature and influences of technological activity.” While these are important issues for technology educators to consider, a more insightful view of technology education would have provided these claims with merit. Such a view would have been particularly helpful for understanding the context of an additional claim that is made concerning the high degree of resistance from students and teachers to many of the changes being advocated.

Discussions of integration in the volume tend to underplay the role and contribution of technology education in relation to the other subject areas. This is evidenced in the following statement which seems to place technology in a marginal location relative to that assumed for science and mathematics:

> The new connections among the disciplines can be seen in the case studies in several manifestations. In some the aim is to relate the science disciplines to one another in what is called 'integration.' Others seek to connect science with mathematics. Still others relate science and/or mathematics with other disciplines such as social science or technology. (p.41)

The limited exploration of the relation of technology education to other areas fails to address such questions as: Is technology education like the other subjects? What does it offer them? What can it learn from them? What does it offer the other subjects? Without this sort of exploration, it is easy for technology to be integrated with other subjects primarily as a resource, as frequently described in the book.

Methodological Issues

The approach taken in this volume to reporting on the case studies raises at least two methodological issues. The first of these is a dilemma which has been played out in other similar projects. By creating a "final distillation" (p. 2) of the 23 case studies, the value of the research in the individual case studies may be compromised. Case studies are studies of the particular (Yin, 1994), and the valuing of the particular was the overall focus of this project.

> [The book] is authentic. In drawing on case studies, we have let the actors in their narratives speak in their own voices, out of their own preoccupations.
> . . . [E]verything that this book has to say rests on the concrete foundation of what somebody has actually done or said, in a specific and well described context of place and practice. (p. 3)

Moving from the case studies, which gain their strength in being grounded in the particular, to a general story removed from any particular context is a complex and problematic methodological move. Can a book which strips the context from the evidence it draws upon make a claim to authenticity on the basis that the context had been accounted for in an earlier form of the work? The dilemma is one that must be played out in order to put the results of 23 case studies in a form that educators and policy makers are likely to read. To its credit, this book did much to keep the individual case studies in view by referring to them and encouraging readers to consult them directly. The book, however, would have gained considerable strength through a reflexive examination of some of the methodological issues addressed in similar projects (e.g., Gaskell, 1996; Stake & Easley, 1978).

The second methodological issue was the decision to postpone making references to literature relating to the science, mathematics and technology education as well as to the theoretical frameworks that were employed until future analysis is carried out. Stated simply, the book is compromised without a bibliography! While this did have the effect of enabling the editors to focus on the important points that emerged from the cases themselves, it also obscured other important points. An instance is seen in Chapter 3, dealing with teaching and learning.

Although constructivism is the only learning theory that is explicitly mentioned, other theories of teaching and learning environments are implied at several points. These include theories of situated cognition and theories of learning styles. A more direct consideration of learning theories would have done much to highlight some important differences underlying the three subjects. For example, while constructivism has been very influential in science education in recent years, technology education has historically relied heavily on theories of experiential learning. By not dealing explicitly with the literature and theory related to the subject matter of the book, the authors were unable to interrogate some of the issues that appear to be germane to the analysis they carried out.

Final Overview

The 23 case studies no doubt provide important contributions to knowledge in the individual subject areas that each addresses. However, *changing the subject* really seems to be about changing *science* education. Technology education is particularly short-changed and an inadequate understanding of this subject is evident.

Fundamental differences between subjects were *not* accounted for in the book, such as the historical differences in the clientele of the various subjects, the different problem solving approaches used in each subject, different ways the practitioners of the three subjects see the world, and how each addresses different human abilities. Despite this overall character to the writing, there is the occasional hint that the authors recognize subject differences, for example, when discussing assessment, they state, “Assessment must be capable of responding differently to the different epistemological constraints that govern the organization of knowledge in each discipline” (p. 98).

Given its descriptive approach, the book falls short of providing an analysis and framework as promised. An analysis of the distinctions between science, technology and mathematics, how and where these subjects intersect and become interdisciplinary or integrated, and the advantages and limitations of integration is research that could lead to a better understanding of the three subjects. A theoretical framework for this understanding has yet to be developed.

Many of the innovations presented in the book are a response to the changing clientele teachers encounter in these subjects rather than to a transformed view of the subjects. New practical demands and a search for relevance are perhaps the greatest drivers of innovation, and may well be the thread that will tie the three subjects together into a fully realized MST subject area.

Despite some of the volume’s shortcomings, it is worthwhile reading for those interested in innovation in science, mathematics, or technology education.

Perceptive insights gleaned from the case studies are discussed in a way that allows readers to begin to appreciate the complicated nature of such undertakings.

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Stoll, C. (1995). *Silicon snake oil: Second thoughts on the information highway*. New York: Doubleday, $22.00, 247pp. (ISBN 0-385-41993-7)

Reviewed by Eli T. Vestich

Snakeoil is defined as any of various substances or mixtures claimed to have miraculous curing capabilities without regard to their medical worth or properties. When proponents of communications and educational technologies speak of endless opportunities and educational experiences, are they offering society a "silicon snakeoil?" These are questions asked in the latest book by Clifford Stoll. *Silicon Snake Oil: Second thoughts on the information highway*, is Clifford Stoll's critique of the Internet, or as Vice President Gore called it, the information superhighway.

Clifford Stoll is somewhat of an enigma in the world of computer science. Heralded as a computer security expert and astronomer, he is known as the man who tracked and caught a German spy ring operating over the Internet. In the summer of 1986 Stoll, a Berkeley graduate student, was employed by the Berkeley computer center. Stoll's first assignment was to track down a seventy-five cent accounting error. It was this accounting error which would lead Stoll on the trail of German computer hackers attempting to steal sensitive military information for the KGB. In the following year, with little or no help from government agencies, Stoll tracked and baited the hackers so that the authorities could have enough evidence to make arrests. Stoll has served as a computer security consultant for the Federal Bureau of Investigation, Central Intelligence Agency, and the National Security Agency. The story of the German computer spy ring is documented in Stoll's first novel, *The Cuckoo's Egg*.

Stoll professes to love his on-line community, yet he is very passionate that the Internet and educational technologies are leading us away from sound educational practices. As technology educators, should we be concerned that sophisticated technological advances may be separating the teachers from the students?

Stoll writes in a very conversational prose which is well suited to emphasize his passion for his ideas. He makes a clear statement that the world on the Internet is a technological fabrication which he fears is being substituted for reality. He compares interactive fantasy role playing games, designed to simulate adventuring into dangerous treasure filled caves and catacombs, to an actual caving expedition where the dangers and treasures are real. Stoll describes the excitement of crawling through actual caverns utilizing his senses and physical stamina, tools rarely used in a computer simulation. He introduces the

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reader to a Chinese astronomer who, using trigonometry tables and twelve abacuses, performs complex astronomical calculations by hand. Due to the inaccuracies of ancient Chinese astronomical records the astronomer had to take meticulous care in developing a method to compensate for the variance in the accuracy of ancient astronomers. Stoll is humbled when he attempts to expedite the astronomers efforts by plugging data into his laptop, when he realizes that due to the nature of the problem, his number crunching machine is worthless. He draws an analogy between USENET and CB radio and compares how each has made a transformation from a communication system to a venue for vilification and profanity. Stoll describes how a perfectly legitimate discussion on Internet bulletin boards can quickly turn into "flame wars" where the individuals trade insults in a manner normally described as libel. With no effective methods of policing the Internet, these situations are increasingly more common and tend to interfere with a valid use of the medium. The USENET is an example which Stoll often uses to describe how a communication system with tremendous potential is wasted on the Internet. He criticizes a failed distance learning program that could have better spent their seven million dollars on teachers and books. Ultimately, Clifford Stoll feels that computers are frustrating, prone to obsolescence, costly, and a distraction to real learning.

Stoll's use of slang and casual tone may be a distraction to readers who prefer formal scholarly work. However, Stoll's tone may be deceptive and could cause one to underestimate the depth of his analysis. Based upon his experience with the networks, Stoll makes many valid points. He argues that teachers should not be so seduced by the virtual world of technology such that they forget that they have real students with real lives and real questions requiring real answers. Stoll also argues that school administrators have a tendency to become overly enthusiastic about bringing computers into the classroom, and he wonders why? The costs of computers do not solve the problems of covering the costs of salaries, books, or paper. Likewise, books, pencils, and paper don't have a street value. Computers and their accessories on the other hand, are routinely stolen from schools. Stoll questions whether proponents of the high-tech classroom have thoroughly examined their position. He argues that when computers break down, they are a distraction to the classroom.

> Try rebooting from a cooked hard disk in front of thirty impatient sixth-graders. Or install a complex piece of software during the ten minutes between classes. This preparation and overhead isn't considered by advocates for the high-tech classroom (p. 127).

The high-tech classroom infringes upon the vital interaction taking place in a student-teacher relationship. Many students are prone to hide behind computer monitors, ignore the instructor to surf the Internet, and avoid taking notes simply because there's a computer terminal where their notebooks should be.

Stoll re-emphasizes his belief that the most comprehensive educational programming and technology systems could never replace a quality teacher. He recalls his own experience in a graduate physics class. The professor is discussing radiative transfer as Stoll is daydreaming in the back of the classroom. The professor realizes that Stoll isn't quite following the lecture and pauses to ask Stoll a few questions. Caught off-guard, Stoll has to think quickly and come up with a valid response. Fumbling through his first few questions, Stoll is skillfully led to the answer by a talented professor, using the only educational tool available; the Socratic method. Stoll states that there are plenty of computer programs that calculate radiative transfer, and even admits to writing some of them. However he believes that there are no software programs which could have taught him "as effectively as goofing off in Professor Marty Tomasko's class did" (p. 120).

Stoll believes that computers inhibit critical thinking and creative thought. It is his contention that science and math-based software programs feed the student someone else's logic instead of encouraging them to develop their own. Clifford Stoll presents an argument that is recurring in the scholarly literature of technology education. Have we become too technocratic? Has the philosophy of technology education forgotten the social ideas of Dewey, Bonser, and Mossman? Stoll speaks of a teenage computer wizard in Berkeley who began using a computer when he was three, but can't hold a normal conversation with an adult. Will this be the outcome of technology education? Are instructors of technology justified to spoon feed a pre-packaged tutorial to their students and let them work at their own pace? Isn't there more justification to initiating topical conversations and cooperative ventures into the classroom? This could create an atmosphere more conducive to problem solving where students are more comfortable to voice their concerns and ideas. Just think, an arena where a quality teacher is given the opportunity to reach the day dreamer and interact in the learning process!

At first glance, it may seem that Stoll is advocating an Orwellian paranoia directed at technology. To the contrary, Stoll believes there are a few flowers in this garden which are worth acknowledging. He recalls a group of seventh grade students using the Internet to exchange poetry; international collaborations in the sciences and humanities; and using the Internet to send specialized mailings for nonprofit groups. Stoll admits that on the first of every month he's involved in the "Great Internet Hunt." This is a contest which is posted every month consisting of various trivia questions. A competitor receives zero points for correct answers but receives credit for how he or she found the answers. This is an application of technology which he feels promotes creative thought.

This book is directed at Internet aficionados as well as the people who are fascinated and anxious to get on-line. Technology education is never mentioned. So why would I recommend this book to the practitioners of our field? I recommend *Silicon Snake Oil* regardless of its attacks on technology. Clifford Stoll's soliloquy is rambling, quirky, and laden with sarcasm. However Stoll writes with conviction and his arguments are not unfounded. If *Silicon Snake Oil* does anything, it encourages the reader to think critically about technology in our society. And after all, isn't that exactly what we are trying to do for our students?

Miscellany

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The *Journal of Technology Education* provides a forum for scholarly discussion on topics relating to technology education. Manuscripts should focus on technology education research, philosophy, and theory. In addition, the *Journal* publishes book reviews, editorials, guest articles, comprehensive literature reviews, and reactions to previously published articles.

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Manuscripts that appear in the *Articles* section have been subjected to a blind review by three or more members of the Editorial Board. This process generally takes from six to eight weeks, at which time authors are promptly notified of the status of their manuscript. Book reviews, editorials, and reactions are reviewed by the Editor and Associate Editor, which generally takes about two weeks.

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1. Five copies of each manuscript *and an electronic version on floppy disk* should be submitted to: Mark Sanders, JTE Editor, 144 Smyth Hall, Virginia Tech, Blacksburg, VA 24061-0432 (703)231-8173. Overseas submissions may be submitted electronically via the Internet (to msanders@vt.edu) to expedite the review process, but if submitted only in ASCII format (e.g. as an email message), a fully formatted version on floppy disk must also be sent via conventional mail.

2. All manuscripts must be double-spaced and must adhere strictly to the guidelines published in *Publication Guidelines of the American Psychological Association* (4th Edition).

3. Manuscripts that are accepted for publication must be resubmitted (following any necessary revisions) both in hard copy and on a floppy disk saved in the native word processor format (such as MS Word) *and* in ASCII format.

4. Manuscripts for articles should generally be 15-20 pages (22,000-36,000 characters in length, with 36,000 characters an absolute maximum). Book reviews, editorials, and reactions should be approximately four to eight manuscript pages (approx. 6,000-12,000 characters).

5. All figures and artwork must be scaled to fit on the JTE pages and be submitted both in camera-ready and electronic formats.

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Errata

Regretably, the final paragraph of Kay Stables' article appearing in the previous issue of the JTE (Volume 8, #2) was missing from the final printed publication. The missing portion is provided below.

— Editor

Providing Coherent, Progressive and Continuous Technological Experiences

.... With hindsight it may have been more productive had such a dialogue been more commonplace in the early stages of developing the National Curriculum.

We were provided a wonderful opportunity by the brave decision to make the technology curriculum in England and Wales compulsory for children in the primary years of schooling. During the first five years of implementing this decision there has been much pain and doubt, many lessons learnt, and also great successes and triumphs. It is hoped that the fruits of this challenged, echoed in the enterprises in many parts of the world, will move us closer to a time when all children will be provided, throughout their whole school life, with experiences and opportunities to develop their own technological capability in a full and satisfying way.

References

(were correct as printed)

Colophon

All manuscripts for the JTE were received in digital format and translated into *Microsoft Word* **using the** *MacLink Plus* **translators. The manuscripts were then formatted in** *Times.* **Page galleys were output to an Apple LaserWriter 16/600PS. The JTE was printed at the Virginia Tech Printing Center. Concurrently, the electronic versions of the files were formatted for electronic distribution via the World Wide Web, and may be found at http://scholar.lib.vt.edu/ejournals/JTE/jte.html. All back issues of the JTE are archived electronically at this URL.**

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