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Guest Editarticle

Lessons From Star Trek: Examining the Social Values Embedded in Technological Programs

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> Mr. Spock: "The needs of the many outweigh…"
> Captain Kirk: "…the needs of the few…"
> Mr. Spock: "…or the one." (Bennett, 1982)

The movies *Star Trek II: The Wrath of Kahn* and *Star Trek III: The Search for Spock* provide this dialogue and serve as the catalyst for reflecting on the interplay between human liberty and technology and how these concepts relate to technological literacy.

Recall that the "Genesis Project" in the movies was a technology to create living planets out of desolate planets. The Federation saw the technology as a means for creation; the Klingons saw technology as a weapon of power. Compare the Federation's relentless search for a planet without life forms so that they might not be damaged and the Klingons' vision of a weapon against life so that they might dominate. The Klingon mentality forces into view the "dark" side of extending our powers over nature through technologies; they can become instruments of power over others. In the apex of the battle to control a technology that can (a) create new worlds out of desolate unpopulated planets or (b) annihilate populated planets, Mr. Spock sacrificed his life for the lives of his shipmates. We see the archetype of reason and rationality manifesting the archetype of human virtue, the sacrificing of his life for others. The crew's exhilaration at their enemy's defeat was palled by the loss of the virtuous Mr. Spock. We are humbled as we recognize that Mr. Spock demonstrated the epitome of nobility. In his eulogistic reflections on his dead comrade, Captain Kirk stated: "I feel I have left the noblest part of myself behind."

Within these scenes, we see the battle that rages between (a) the appropriate objectives of technology and (b) the exercise of personal liberty. Are these concepts related, as Roddenberry, the author of *Star Trek*, hints, or are they virginal concepts that must retain their independence and purity? To thrust us further into the quagmire, we observe a different demonstration of virtue in *Star Trek III: The Search for Spock.* Valchris, a Klingon warrior, acquires secret information about the Genesis project and provides it to her commander; she looks at the information and thereby sacrifices her life. She willingly accepts taking her life, by her commander, for the common good. Her demonstration of virtue demanded the relinquishing of her liberty, and ultimately her life, by the imposition of the "state's" power to determine the common good. Spock's demonstration of virtue illuminates, on the other hand, the freewill decision to sacrifice his life for his shipmates.

It is the supposition of this article that the concepts of personal liberty and technology exploitation are inseparably intertwined and that literacy in technology must include the issues of power, liberty, and virtue. Lewis (1996) suggested in his essay on *The Abolition of Man* that "what we call man's power over Nature turns out to be a power exercised by some men over men with Nature as its instrument" (p. 66). As a result of their ability to apply and withhold technology, some nations will have power over other nations, majorities will have power over minorities, and governments will have power over people (Lewis, 1996).

Kasson (1986), in an analysis of the interplay between American independence and American industrialization between 1776 and 1900, provided insight into the often overlooked relationships between personal liberty and the exploitation of technology. Kasson meticulously analyzed the transition that occurred as "technology came to be regarded as essential to American democratic civilization" (p. 3). This paper reflects on the salient points identified by Kasson and their possible manifestations in modern life.

First, the ideology of republicanism (Kasson, 1986), as it appeared in the 18th and 19th centuries:

> … began with a conception of the relationships among power, liberty, and virtue. The balance among these elements … remained delicate and uneasy at best. Power, as they [Americans] conceived it, whether wielded by an executive or by the people, was essentially aggressive, forever in danger of menacing its natural prey, liberty or right. To safeguard the boundaries between the two stood the fundamental principles and protections, the "constitution," of government. Yet this entire equilibrium depended upon the strictest rectitude both within government and among the people at large. To the eighteenth-century mind republicanism denoted a political and moral condition of rare purity, one that had never been successfully sustained by any major nation. It demanded extraordinary social restraint, what the age called "public virtue," by which each individual would repress his personal desires for the greater good of the whole. Public virtue, in turn, flowed from men's private virtues, so that each individual vice represented a potential threat to the republican order. Republicanism, like Puritanism before it, preached the importance of social service, industry, frugality, and restraint. Their opposing vices–selfishness, idleness, luxury, and licentiousness–were inimical to the public good, and if left unchecked, would lead to disorder, corruption and ultimately, tyranny. The foundation of a just republic consisted of a virtuous and harmonious society, whose members were bound together by mutual responsibility. (p. 4)

This description of republican virtue maintained that the greater good of the people could be encouraged when individual members of society set aside their personal desires. Voluntarily relinquishing personal desires for the common good was the freedom of choice that personal liberty sought to maintain. The protection of this right was bound up in a precarious balance between the rights and responsibilities of individuals, organizations, and governments.

Kasson (1986) described several factors that caused changes in America's conception of republican values. These factors were related to the adoption of technology during the period of American industrialization. Kasson presented a clear understanding that Americans believed the advocacy of manufacturing technology was a means of achieving liberation from English oppression. English oppression manifested itself in a forced American dependency on imported goods. America exported raw material to England where it was processed into finished goods and then reintroduced to America, at a higher price. Americans felt that the economic dependency on English manufacturing for finished goods was a threat to their personal liberty and, thus, a threat to republicanism and the very success of the United States.

The American response was to emphasize the contradictory relationship of republicanism and economic dependency as a result of the importation of manufactured goods. Resistance to a dependency on imported goods manifested itself through renewed adherence to the republican values of frugality, personal industry, and, now, domestic manufacturing. Americans could demonstrate their virtue by refusing to consume English goods and purchasing only American goods even though the American goods were higher priced and of inferior quality. As a result, "technology emerged as not merely the agent of material progress and prosperity but the defender of liberty and instrument of republican virtue" (Kasson, 1986, p. 8).

Once technology, as a tool for resistance, had served its purpose, American values underwent additional modifications in its support of technology. America viewed itself as a nation that acquired its virtue from agrarian endeavors. To work and conquer the land was a true demonstration of republican virtue, vitality, and godliness (Kasson, 1986). Many perceived manufacturing as a threat to republican virtue since it was not agrarian. Manufacturers fought to establish the relationship between manufacturing and the control or submission of nature, which was the intended purpose of humankind. In their eyes, manufacturing and farming were both capable of fulfilling the human purpose: to harness, to control, to exploit, and to subdue the land. Frugality and industry, it was argued, required the pursuit of both agriculture and manufacturing.

However, due to the shortage of skilled farm labor, many were concerned that manufacturing would draw the skilled workers away from the farms and into the cities. Manufacturers countered with the suggestion that the development of labor-saving devices would help alleviate the shortage of skilled labor on the farm and in the factory. Technology was portrayed as essential to the fulfillment of America's purpose, and the new technology of manufacturing was believed to be the solution to not only a shortage of skilled labor but to the ultimate fulfillment of America's destiny.

Manufacturing advocates continued to stress the threat to republican values and American strength from an economy based on the exportation of raw materials and the importation of finished goods. They stressed that public virtue could best be achieved through an autonomous and balanced economy based on domestic manufacturing. Buying American goods and refusing to purchase English goods was an exhibition of patriotism. Thus, patriotism became linked to republican values and to domestic manufacturing. This linkage also resulted in a stronger national government dedicated to developing manufacturing technology and republicanism.

Labor abuses, as evidenced in English manufactories during this period, were identified as being technological in nature and could be remedied in American manufactories through the purposeful application of technology. Improvements in diet and living conditions were two of the suggested technological solutions. Tenche Coxe, an 18th-century planner of industrial towns, articulated his position that manufacturing would be able to employ the unemployed and the marginal workers and thus keep them from contributing to the social problems that were evident at the time (Kasson, 1986). Technology was perceived as a remedy for social problems and as a positive agent for promoting social virtue.

During the later half of the 18th century reliance on the self-restraint of individuals could no longer be relied on. This absence of self-control threatened republican virtue. The factory setting, though, with its regularity, uniformity, and subordination was viewed as the solution, capable of exercising social control on the undisciplined. Factories were organized so that they might exert complete control over the person's work environment, and also over their home and social environments. Company officials used this social control to reject shorter working hours. They sought to limit any form of individuality because uniformity promoted their vision of the common good. The precarious equilibrium of rights and responsibilities of individuals, organizations, and government, on which republicanism depended, tilted in favor of those who controlled the technology.

Technology, promoted as a tool for liberation, was transformed into a tool for domination. Those who were in control and sought to capitalize on their positions of power perpetuated this transformation. Instead of fostering the ideology of republican virtue, technology, through its owners, became an agent of social control. Individuals lost their right to participate in the process of freedom. Individual liberty was reduced rather than increased. The result was the antithesis of republican virtue. Individuals no longer had a choice as to how they could exhibit their republican virtue. Those in power, those who owned the technology, mandated it.

In describing the writers of utopian literature during the 19th century, Kasson (1986) stated:

> In a society whose republican purposes had been obscured or corrupted, these writers emphasized that technology itself might serve as an instrument not of liberty but of repression, not order but chaos, not creation but destruction. The hopeful vision of an integrated technological republic struggled against the dreadful anticipation of technological tyranny and holocaust. (p. 191)

Did republican values influence the application of technology so that social justice, participatory freedom, and democratic ideals were upheld or did the utilitarian use of technology compromise republicanism? Through the 18th and 19th centuries America attempted to moderate and influence technology through its adherence to republican values. What one finds, though, is that the application of technology for production purposes, with a justifying agenda of social control for the common good, influenced and modified republican values. Technology, in essence, was not just more resilient to external influences than was republicanism, than was American culture, it was in fact the initiator of cultural change. Republicanism, the dominant ideology of the period, succumbed to the promises of the technology system designers. The interplay between power, liberty, and virtue mutated into a mentality that the virtuous ones, those who had the common good in mind and who also had the power of technology firmly in hand, were justified in exerting their influence over the liberty of the individuals. And the worker unknowingly traded his or her liberty for the promise of employment, comfort, and security.

The American revolutionaries sought to establish a land where authoritarian control of the masses by kings would no longer occur. Kingdoms, as organizations, were effective in establishing order and providing military protection and stable reserves of food. They were effective systems for maintaining and extending the effective influence of the king. However, kingdoms also developed systems of forced labor, forced military conscription, and bureaucracies that used people for its divinely empowered kings (Hughes, 1989). These systems were accepted because they offered, through the effective unifying of scattered and diversified human activities, security and an economy of controlled abundance. The construction of systems to provide "unity from diversity, centralization in the face of pluralism, and coherence from chaos" (Hughes, 1989, p. 52) frequently involves the destruction of preexisting systems.

Mumford (1991) wrote:

> At the very moment Western nations threw off the ancient regime of absolute government, operating under a once-divine king, they were restoring this same system in a far more effective form in their technology, reintroducing coercions of a military character no less strict in the organization of a factory than in that of the new drilled, uniformed, and regimented army. (p. 375)

The solution to the problem that confronted early Americans was the establishment of a stable economy that would, in turn, foster independence. To this end, domestic manufacturing was promoted. The promotion of manufacturing included its alignment with the republican values of frugality, industry, and restraint as well as its alignment with agriculture as a means to harness and exploit nature. Initially, the republican value system was perceived as the context in which manufacturing technology was applied and not a system variable. Hughes (1989) in an analysis of the evolution of large systems stated, "Over time, technological systems manage increasingly to incorporate environment into the system, thereby eliminating sources of uncertainty…" (p. 53). Kasson's (1986) description indicates that the republican value system eventually came under the control of the system designers. Hughes suggested that as external factors become interdependent components of the system, system builders "have tended to bureaucratize, deskill, and routinize in order to minimize the voluntary role of workers and administrative personnel in a system" (p. 54).

As the manufacturing system matured in American history, one observes that personal values conflicted with the promotion of the common good; efforts were then directed at changing people's values through the development and application of manufacturing technology. The social foundation of republicanism shifted from a contextual environment to a variable of the system under the control of the system designers.

Thus, liberty (as an element of technological literacy) became entwined with the choice to extend or restrict personal freedom. In his book *Ethics in an Age of Technology*, Barbour (1993) described two sides of freedom: (a) the absence of external constraints and (b) the presence of opportunities for choice. The absence of external constraints offers freedom from external coercion and direct interference by other persons or organizations. This aspect of freedom tends to focus on limiting the power of organizations to constrain the individual. The presence of opportunities for choice seeks to provide genuine alternatives and "the power to act to further the alternative chosen" (Barbour, 1993, p. 39) This aspect of freedom relates to the autonomy of the individual and the equal access to choices. Whichever side of freedom one chooses to emphasize, it is apparent that as technology develops, opportunities arise, which limit personal freedom by those in control of the technology—whether it is by direct interference and coercion by the organization or by limiting the opportunities for legitimate decision making. Kasson's (1986) analysis indicated that the advocates of manufacturing technology in early America exercised coercive influence to change American values and also sought to limit their opportunities for real choice. One wonders if this is also true for modern Americans.

Modern day influences of technology on American culture today are so prevalent as to go virtually unnoticed. The technological environment deadens one's senses to its influence. Ralph Waldo Emerson, enamored with his first train ride, noticed how railway workers were "impervious" to the presence of a train when it passed by (as cited in Kasson, 1986). As technology surrounds us, we grow indifferent to its presence, to its novelty. Likening technology to a painkiller or narcotic, Shallis (1984) suggested that numbness is a reaction induced by technology. Riding in a train or a car, one becomes numb to the surroundings. In a technological world where the only constant is change, novelty and innovation quickly become banal. Our lowered sensitivity to the multidirectional aspects of technology development and application masks the damage that may be inflicted on the unsuspecting.

Another effect of a narcotic is addiction (Shallis, 1984). We are unable to do without technology. We use it even when we don't need it. In a staff meeting held in a sunlit room, my supervisor asked if we should turn on the lights. We drive to the mailbox and use calculators for simple math. We are unable to turn off the television after only one show. We populate our houses with remote control devices for our entertainment technology and scurry about frantically searching for the television remote control when it would have been quicker to walk across the room and change the channel. We talk on the phone while walking, playing, shopping, and driving. People now carry beepers and phones wherever they go.

We have become addicted to technology. We then unconsciously adapt ourselves to the technology. We purchase products based not on our needs, but on the novelty of a product. We get a "rush" from the new acquisition. Then we search for another fix. For example, the proliferation of cellular phones raises interesting questions. Was it the need to communicate instantaneously that promoted cellular phone development? Or has the technology influenced our values? Have we developed the need to communicate instantaneously because the technology was promoted? We are seduced into complacency by technological development without philosophically examining our material choices.

> The early part of the 20th century was the advent of the consumer economy. [B]usiness leaders realized that in order to make people "want" things they had never previously desired, they had to create "the dissatisfied customer." Charles Kettering of General Motors was among the first to preach the new gospel of consumption. GM had already begun to intro duce annual model changes in its automobiles and launched a vigorous advertising campaign designed to make consumers discontent with the car they already owned. "The key to economic prosperity," Kettering said, "is the organized creation of dissatisfaction." (Rifkin, 1995, p. 20)

This addiction to technology may be a result of the deliberate manipulation of the republican American values to promote the agenda of manufacturing. Today, that same restraint—frugality and even intelligence—are seen as sales resistance (Lewis, 1996) and not as virtues.

Have we lost our ability to make decisions about the development and application of technology and its systems? Are decisions now made for us that we do not know about? We tacitly accept the mundane limitations of choice (i.e., "Why must we buy four AA batteries when we only need one? Why do we have to have VCR+ on our new VCRs?). Are the controllers of technology systems determined to limit our choices we have to the selection of features, color, and quality through the altering of our value systems?

Technologically literate citizens must ask: "Are our values influencing the development and application of technology, or are our values being influenced by the designers of technology systems for objectives other than the pursuit of happiness, liberty, and life?" We might even want to ask, "Are our values changing simply because the technology is now available?"

Machines do not decide how a product should be packaged or manufactured, but the owners and managers of the technology do. I can have any color I want, "so long as it's black." I can use any Internet browser I want, but this one can't be removed from the operating system. Others are making the decisions for me, based on their perception of what is right or best for me, based on their perception of the "greater good." Our ability to make decisions has been usurped; we did not even realize that we gave up our rights.

Admittedly, I gained some immediate gratification and even some long-term benefits. My liberty has been restricted but I am content, as long as there are batteries to buy and free Internet browsers. As long as there is an abundant supply of goods, I am not likely to rebel against the technological tyranny that has usurped my freedom. As long as there is access to whatever I desire, I am not aware or even concerned that my freedom has been usurped. In fact, I am content with the situation and live under the false belief that I have total liberty because I have an abundance of opportunities for choice.

> The bargain we are being asked to ratify takes the form of a magnificent bribe. Under the democratic-authoritarian social contract, each member of the community may claim every material advantage, every intellectual and emotional stimulus he may desire, in quantities hardly available hitherto even for a restricted minority: food, housing, swift transportation, instantaneous communication, medical care, entertainment, education. But on one condition: that one must not merely ask for nothing that the system does not provide, but likewise agree to take everything offered, duly processed and fabricated, homogenized and equalized, in the precise quantities that the system, rather than the person requires. Once one opts for the system no further choice remains. (Mumford, 1991, p. 376)

Synthesizing Kasson (1986), Mumford (1991), and Hughes (1990), one sees that the value system of a group is more appropriately viewed as a variable of the system—since it is under the control of others—and not as the environment of the problem. One finds that human values, as a variable of a technological system, became an output variable of a subsystem within the larger technological system (Hughes, 1990). In essence, the means became the ends. In discussing technical activities and human aspirations DeVore (n.d.) stated:

> Technology is a very human thing because man created it. But it creates cultural and social problems which must be understood if man is to attain both order and freedom. In essence, the problem is how to have the best of both the technical and the social worlds, how to realize the potentialities of technology without subordinating the ends to the means. (p. 13)

As advocates of technology we must analyze the complexity of the technological systems we support. We must seriously ask if the legitimate output and evaluation of any technology system should be limited to a simple plethora of material choices. We must move beyond the belief that the totality of "human needs and wants" we so adamantly include in the definitions of technology are limited to artifacts and their consumption.

As *human* technologists, we should also consider the legitimate outcomes of our technological activities as those that dignify rather than degrade, that humanize rather than dehumanize, that liberate rather than oppress. The study of how technology is developed and applied to meet "human needs and wants" should not be constrained to the techniques of designing, using, and producing artifacts and systems but must include the promotion of the "inalienable rights" of all human beings: life, liberty, and the pursuit of happiness. The technologies, the systems, and the owners that impinge on these rights must be rigorously scrutinized. The opportunity and ability to scrutinize technology is a right and a responsibility of all, and it must be *the* foundational skill of a technologically literate person.

In this article, I have attempted to illuminate the relationship between technology, power, and liberty during the formative years of the United States. The past, present, and, indeed, the future are linked by the opportunity to exercise personal liberty (Marcus & Segal, 1989). Have modern Americans, just as the early Americans, had their liberties unknowingly expropriated? Are we, to some extent, analogous to the Klingon warrior Valchris, who exercised choice but had lost freedom? We believe we have freedom, but we really only have predetermined choices.

This is the central danger of technological illiteracy: that we do not know how others are using our dependence on technology to encroach on our liberty.

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Editor's Pages

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Epsilon Pi Tau Matters in Enriching Professional and Personal Lives

Jerry Streichler, Contributing Editor

This is a profile of *Epsilon Pi Tau* (EPT), an organization that plays a significant role in our relatively new professions. To this end, a brief history is set in context. This is followed by an enumeration of EPT activities to achieve different purposes: recognize and contribute to the professional development of individual members, promote and advance the academic programs with which members are associated, and support and promote professional organizations in technology. Anecdotes of incidents and events are selectively interspersed in the enumeration to exemplify and give life to these items. The paper closes with some thoughts about EPT on the international level.

A Context for *Epsilon Pi Tau*

The *Handbook of College Honor Societies* (1998) reveals an intriguing history of these societies in higher education in the United States. The first honor society, *Phi Beta Kappa*, was organized in 1776, but the movement really grew dramatically in the early 1900s. Virtually every higher education discipline or professional field of study has an associated honorary group. There are also societies which do not identify with a specific discipline and, like *Phi Beta Kappa*, are dedicated to general studies or emphasize recognition of leadership among the higher education students.

For their ceremonies, many honor societies borrowed their language, form, and ritual from religious European groups like the Masons. Consequently, the ceremonies have a degree of drama and mystique. But the messages in the honoraries' ceremonies are very different. Typically, they are not secret. They express the values of that society and its moral obligations. They stress the importance of the discipline associated with the honorary. The honorary organizations have not been based on social class distinctions or any other social hierarchical criteria. But they are *elitist* because they focus on recognizing and rewarding "...high achievement in undergraduate, graduate, and professional studies, in student leadership, and in various fields of research" (p. 104, back cover).

EPT interprets, acts upon, and adds to this principle in ways that distinguish it from other honor societies: (a) It conducts a continuing career-long program to serve professional development needs of members; (b) it acts upon the meaning of leadership by recognizing leaders in academe, government, and the private sector; and (c) it has a long-standing international outlook.

In seeking to best serve student members, two critical activities have emerged; their achievement results in a richer program for all members. These are (a) EPT extends its recognition and membership program to faculty, industrialists, practicing technologists, and others who are supportive of the study of technology; opportunities to interact with such models of success in the technology professions is clearly an enrichment for student members; and (b) EPT welcomes accomplished students, faculty, industrialists, and practicing technologists from throughout the world; thus, synergistic and enrichment opportunities accrue to the entire membership. (It should be noted that this worldview was influenced and first implemented by EPT's founder and first executive secretary, William E. Warner, who was prescient, to say the least.) Warner had used the term "International" almost from the organization's inception, and in combining their deference to him with a forward-looking use of the term "technology," the EPT board of directors, almost 25 years ago, adopted the still-used EPT descriptor: "The

International Honorary for Professions in Technology."

These guides to EPT operations have resulted in an organization that has initiated more than 70,000 professionals since 1929, and currently lists more than 12,000 members who reside in 49 countries. They include students enrolled on the associate through the doctoral degree levels. Those in the education professions include administrative leaders, teachers, and professors from precollege to university levels who are associated with the subject matter of technology: science; science, technology, and society; or training and workforce development. Also among EPT members are scientists, practicing technologists, and industrialists who have a keen interest in technology, and trainers and human resource development personnel who also maintain a keen interest in the phenomenon of technology and have been supportive of the advancement of the field.

Recognizing and Contributing to the Professional Development of Members

On Recognition

A recent incident tells more about the meaning of recognition than any formal definition or human development jargon. The setting could have been an initiation anywhere in the world. But this one took place this past spring at an EPT-conducted Exemplary Initiation in Salt Lake City, Utah, during the annual conference of the International Technology Education Association (ITEA). One of the initiates was a senior professor from a distinguished university in an eastern Mediterranean country on assignment to a prominent university in the American West. At the close of the ceremony I moved to his side to shake his hand and extend words of welcome. He could not contain himself. "This is a wonderful experience," he remarked. "It is something that we must do in my university. We do not do enough of this sort of thing and yet we have so many deserving faculty and students who can benefit from it."

This speaks volumes about the human need to be recognized by peers. It is true that most institutions of higher education have programs that recognize academic and even leadership accomplishments and promise. But EPT conveys a deep recognition that is very much valued by peers. Further, in the United States and increasingly in other parts of the world, this sort of recognition is becoming as valued outside of the academy as it is within the academy.

The EPT recognition program goes considerably beyond a member's initiation:

- For continuing professional accomplishments, active members can be recognized and elevated to Laureate and Distinguished Service membership, the latter being the highest award bestowed upon members. They may be recommended for these honors by fellow members, chapter leaders, or the board of directors.
- Members in every student, faculty, and practitioner category are eligible to participate in the annual W. E. Warner Awards Program competition. Essay and research products, leadership, and professional practice accomplishments are evaluated. Had there been a full complement of competitors and winners this year the total value of awards would have been US$12,000.

On Professional Development

Two anecdotes, separated by many years, are related here. One describes my personal experience as a student leader in an EPT chapter many years ago. The second, which occurred this year, is an example of how EPT serves faculty.

1. EPT chapters at institutions provide a venue for students to engage in meaningful, and sometimes rare, leadership development experiences. As an undergraduate chapter member, I had a profound experience. I was directly involved in all aspects of an effort to award Epsilon Pi Tau International Honors Citations to Walter H. Brattain and William B. Shockley, 1956 Nobel prize winners in physics, for developing the transistor. With a co-trustee mentor, the other student chapter members and I researched the scientists' accomplishments, communicated with the EPT executive secretary at the International Office, produced citation drafts, planned and implemented the event, invited the honorees and city and university dignitaries, and played an instrumental role in conveying the awards.
2. This past year, one EPT member, a professor at a

German university, sought EPT's assistance in arranging an upcoming sabbatical during which he could spend some time doing research and development at a university in the United States. EPT put him in touch with professors at two major American universities, one in the northeast and one in the southern middle west. The three are sharing their common interests in computer multimedia applications in technical instruction and training situations. Exchange visits over the next year will culminate with the professor from Germany serving at one of the American universities next summer.

Other EPT services also contribute to professional development:

- Scholarship grants to rising leaders to attend important conferences.
- Providing *The Journal of Technology Studies* to all members is in itself a developmental approach. Another guiding editorial philosophy contributes to professional development of new and emerging researchers and authors. The editors consider authors part of a team whose purpose is to produce a publishable article via diligent attention and communication.
- Other EPT publications include informative newsletters and research-based monographs.
- Via the Internet and the EPT website, members can communicate directly with one another or use the services of the International Office to provide a forum to exchange ideas among the diverse membership.

Promoting and Advancing Academic Programs

Although the recognition program is basic to EPT efforts, it should be clear by now that EPT's policies are guided by the notion that academic programs connected with chapters or with which members-at large are associated should enjoy benefits as well. The citation to the two Nobel Laureates described above was not only a significant leadership experience for students, it also resulted in considerable positive visibility for the academic department and should be considered as a device for promoting programs:

- The Certificate of Commendation and the International Honors Citation (the latter being the highest honor that EPT bestows on nonmembers) can be recommended by members-at-large or by chapters to be awarded to benefactors of academic programs with which the members are associated. EPT records show that university presidents, chief executive officers in the private sector, and high-ranking government officials who have been benefactors (donated funds, provided cooperative education opportunities, funded research, etc.) of the academic programs have been nominated and approved by the EPT board of directors to receive such honors.
- Academic program leaders may encourage the EPT chapter to initiate deserving individuals from other technology-related fields within their own or nearby institutions. For example, in addition to the faculty in the various technology preparation programs, science, mathematics, and social science instructors may become involved. Perhaps instructors and staff persons and students who meet informally about computers and other technology advances may be invited to join. Also, teachers in pre-college and pre-university schools who are involved with science and technology in formal instruction or with extracurricular student organizations can influence talented students about their choice of higher education studies. Relationships with these students can be strengthened by offering them initiation into EPT or awarding them an Epsilon Pi Tau Certificate of Commendation.
- Establish a presence and connection with business, industry, and nearby institutions of higher education and develop programs, visits, or invite speakers to chapter programs. Individuals who may not be members qualified as a result of professional accomplishments should be invited to be initiated. One can only imagine the opportunities that may benefit both students and faculty. Cooperative research and development projects and other ventures could, likewise, emerge.
- At critical times, EPT used its prestige and leverage in behalf of academic programs that were threatened by political pressure from outside or within the academy. More often than not, threats to the academic unit in technology were removed, in part, due to EPT efforts.

Working With Professional Organizations

It can safely be said that in the United States the leaders of most professional organizations that serve technology education are members of Epsilon Pi Tau. It is also true that a growing number of leaders of such organizations in other nations have become members in recent years. EPT policy has long held that the growth, strength, viability, and vitality of a profession depends upon strong and well-led professional organizations. In the late 1930s, William E. Warner, who founded EPT, was instrumental in founding the American Industrial Arts Association, now known as the International Technology Education Association (ITEA), and EPT has been active in supporting existing organizations that serve different areas of specialization in technology studies. As new fields or emphases have emerged in response to a logical need for a new professional group, EPT has bolstered their development. Here are some examples:

- EPT is the official honorary of the National Association of Industrial Technology and the World Council of Associations in Technology Education and is being considered for that distinction by other groups.
- EPT has responded to proposals from organizations to fund specific projects. For example:
    1. With a requirement that the funds be matched by contributions from other sources, EPT provided partial support that enabled a new professional organization to develop a special conference session at which representatives of several engineering disciplines reviewed and discussed science, technology, and society principles to be taught at pre-college levels.
    2. Having identified promising scholars, organizers of an international conference sought resources to enable the scholars to attend the conference. The EPT board responded positively to the proposal and made the award to individuals to attend the conference as “EPT Scholars.”
    3. Initial seed funds provided by EPT resulted in sufficient matching funds to enable the National Association of Industrial Technology (NAIT) to produce *Industrial Technology, Tomorrow’s Technology Today,* an interactive CD. Designed for secondary school students, it contains information about industrial technology careers and preparation opportunities in community and technical colleges and universities in the United States. In a pilot distribution, NAIT supplied copies to 4,500 high schools in five states; NAIT’s goal is to reach all U.S. high schools.
    4. EPT participates in international, national, and regional conferences. It also supports the work of 15 professional organizations that serve the entire spectrum of the technology professions.
    5. EPT is a founding member of the World Council of Associations in Technology Education (WOCATE). This last statement provides an excellent segue into EPT efforts on the international level.

On the International Level

While the initiation I described earlier in Salt Lake City took place in the United States, the team that conducted the ritual represented EPT’s flagship Canadian chapter from the Province of Alberta. But the team was not entirely Canadian—it included professors from Japan and the United Kingdom. The initiates that day were even more diverse with representatives from Australia, Canada, Finland, France, Israel, Japan, and the United States. But there is more to our international story:

- It was inevitable that the EPT chapters in several of the major PhD-granting U.S. institutions would initiate degree candidates from other lands. This accounts for part of EPT’s international membership. In the past decade, however, EPT has been actively supporting and partially sponsoring international conferences and organizations (EPT’s status as one of WOCATE’s founding organizations has already been mentioned). Further, last September I was pleased to represent EPT as one of the sponsors of the International Conference on Technology Education at the Technical University of Braunschweig which was attended by more than 180 world leaders in technology studies, to present a paper on which this edarticle is based, and to conduct an Exemplary Initiation of new EPT members, leaders from France, Germany, Israel, Nepal, New Zealand, Russia, Taiwan, Uganda, United Kingdom, and the United States. I also had the privilege of presenting an International Honors Citation to a German professor in recognition of his superlative leadership and exemplary scholarship over a long and highly productive career. EPT has served similarly in conferences in Weimar, Banksa Bystrica, Paris, Jerusalem, and Washington, DC. At those conferences accomplished leaders from Australia, Finland, France, Germany, Greece, Japan, The Netherlands, Poland, Kenya, India, South Africa, and the United Kingdom were initiated as members, Laureate and Distinguished Service Citations were also awarded to deserving members.

- Another index that exemplifies EPT's international reach is the increasing percentage of non-U.S. authors in recent issues of the EPT-sponsored *Journal of Technology Studies* (up to 40% in the Winter/Spring 1999 issue).

Coda

Let me close by revealing how all this is done: All EPT leaders serve on a voluntary basis without compensation, although expenses incurred in connection with EPT service are reimbursed. Annual dues are kept to a minimum, sufficient to ensure that operating, including publication, expenses are covered. In the past 25 years, EPT has built an endowment fund primarily from donations. The bulk of the endowment is guaranteed to be maintained in perpetuity. Earnings can only be used for development purposes and for awards. Earnings have increased each year, thus enabling the honorary to accomplish even more than initially envisioned. The essential incentive for EPT leaders is to promote excellence in preparation and in the practice of professionals who comprise the fields. A key element in accomplishing and ensuring excellence is reaching the talent in all venues in every country and by encouraging sharing of ideas between and among the wonderful, creative, and productive minds that inhabit the technology professions...and, of course, in recognizing them in the EPT manner.

Dr. Jerry Streichler is Trustee Professor Emeritus of Technology and Dean Emeritus of Bowling Green State University's College of Technology. In addition to being Epsilon Pi Tau's Executive Director, Streichler holds the Epsilon Pi Tau Distinguished Service Citation and is a member of Alpha Gamma Chapter.

This article is based on a presentation made at the International Conference on Technology Education at, the Technical University of Braunschweig, Germany, September 24-28, 2000. The conference was organized by co-directors: Dr. Ing. Professor Walter E. Theuerkauf of the Technical University of Braunschweig and Dr. Michael J. Dyrenfurth of the Iowa State University under the auspices of the World Council of Associations in Technology Education (WOCATE) and underwritten by UNESCO, several universities, the German Ministry of Education, and the State of Lower Saxony. Epsilon Pi Tau was among these groups whose support–along with the heroic work of its organizers and a talented staff at the Technical University–enabled this successful conference.

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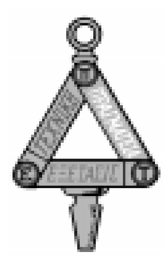

Training for Tomorrow

Ce Ce Iandoli, Editor

Three years ago I worked as a faculty intern at a software development company in San Francisco called Macromedia. Macromedia creates software that lots of you may know about: Director, Flash, Shockwave. My job was to walk around in a somnambulant state dreaming of how we could design the home page so that as soon as a user placed her toe on that site, she would be siphoned off to the exact place she needed to go. This was a big deal because there are 18,000 pages sitting under the macromedia.com site and over 3 million people come to it daily.

What tools could I possibly use to answer that technologically-rich question? Colored pencils, colored papers, notes and squiggles, conversations that resulted in no answers, brainstorms and a wild imagination. What was my deliverable? A highly complicated map, resembling a 3-d flowchart, with a psychological quiz for my fictional user. Example, “How do you feel about using computers?” a. Fearful. b. Curious. c. Excited. Really.

Fast forward to another training experience I had just this past fall: I needed to learn web animation software that was especially dense to learn in time for a class about to begin in three weeks. So, I buy 2 books, one containing a CD-ROM with QuickTime movies of how to do things. I insert my CD; play my lessons. Try out the tutorials. And when I get stuck, I look under the ŒHelp, menu. I consult a second book with exercises and pictures which promise me everything will be ok, if only I’d submit to their advice. All of this doesn’t do enough for me.

I call a friend who knows Flash (Milissa) and we invite (Sarah) and we meet every Tuesday for months, studying, drinking wine, hating some parts of the program, despising our own slowness at this task, and ultimately, triumphant on two counts: our friendships have deepened alongside our skills. The social/collaborative model worked better for me. When I go to class my teaching assistant who knows more than me (Avery) and my students teach each other tricks and learn the snafus and the quirky fetishes of this new software. Ergo:peer learning.

In this edition of our journal, we watch our authors grapple with new paradigms for training tomorrow’s technologists. We make our students think up and down, horizontally and vertically; strategize, doodle, talk with each other; examine how they know what they learned.

We ask them to think about thinking; we insist on self-examination. We create dyads; we listen to what they say as they construct something to catch a phenomenological glance at what matters to them as they work, in teams, in same sex teams, with paper and scissors, and lots of scotch tape.

The tools we need for what comes next are filled with uncertainty. What shall tomorrow’s technologists rely on?

We honestly aren’t sure. So we rely on our wild imaginations, the logic of critical thinking, and tools that contort everything into 2 and 3-d hopes.

Although we get lost when we stretch to imagine tomorrow’s technologists, we need to imagine them as us. And ask something tougher. How shall we talk to them about what we love? And how shall we explain what’s lasting and therefore, pretty unimaginable? And how shall we encourage the tension between what’s creative and what’s feasible?

Articles

Using Portfolios to Enhance Creative Thinking

Moshe Barak and Yaron Doppelt

Education has long emphasized imparting cognitive competencies, such as logical-mathematical thinking, problem solving, and creativity, along with social and personal competencies. Infusing metacognition thinking skills into any course may provide a rich learning environment while also contributing to a better understanding of the discipline under study (Ennis, 1989; Glaser, 1993). The constructivist learning approach also emphasizes these principles: Learning is an active process; the learner absorbs information from the environment and derives meaning from it; learning needs to relate to pupils' daily lives; meaningful assignments place responsibility with the pupil and gives him or her freedom; and activity-based practice involves planning and constructing products and systems in an environment outside the school (Brooks & Brooks, 1993).

Computerized technological systems can provide a rich learning environment which can expose the learner to a variety of experiences such as true modeling, simulations, building models that represent formulas, algorithms, graphics, and animation. One of the better known examples of such a rich computerized learning environment is the LEGO-Logo system. Resnick and Ocko (1991) believe this learning environment puts children in control since they formulate their own designs and experiments, and work on projects that they care about personally. Project learning also encourages pupils to work in teams (Barak & Maymon, 1998; Barak, Maymon, & Harel, 1998; Denton, 1994). In this way, pupils combine "hands-on" activities with what Papert (1980) has termed "heads-in" activities.

Despite the increasing recognition of the educational importance of rich learning environments and project-based learning, many educators do not have sufficient tools to realize the potential of technology education in fostering the development of higher order intellectual skills. Thus, it's crucial to delineate the higher order thinking skills we wish to inculcate as we search for ways to manifest them in pupils' work.

Creative Thinking as a Synthesis Between Lateral and Vertical Thinking

De Bono (1970) differentiated between two types of thinking: lateral thinking, which refers to discovering new directions of thinking in the quest for a wealth of ideas, and vertical thinking, which deals with the development of ideas and checking them against objective criteria. Vertical thinking is selective and sequential; it moves only if there is a direction in which to move. Lateral thinking is generative; it can make jumps and moves in order to generate a new direction. Lateral thinking does not have to be correct at every step and does not use fixed categories, classifications, or labels. Vertical thinking selects the most promising approach to a problem while lateral thinking generates many alternative approaches. According to De Bono, the processes of vertical and lateral thinking are both essential. Creative thinking is a synthesis of lateral thinking and vertical thinking, each complementing the other.

This view of creative thinking differs from the traditional approach in which curricula and research address creativity, mathematical-logical thinking, and critical thinking as separate entitities. Waks (1997) claimed that education-for-all programs should introduce lateral thinking habits in addition to the traditional vertical thinking ways stressed in the past. Scientific and technological changes in everyday life call for the ability to handle new situations.

Portfolio Assessment

These changes in teaching methods and learning environments necessitate new methods for assessing students' achievements. The concept of alternative assessment includes a variety of methods including performance assessment, open-ended problems, interviews, journal writing, exhibitions, oral examinations, and peer evaluations. All these evaluation tools are intended to promote learners' competencies in the cognitive area as well as the metacognitive area, interpersonal arena as well as personal development (Gredler, 1995). These complicated competencies do not lend themselves to assessment by methods based on question and answer tests (Berenson & Carter, 1995). Alternative assessment is an integral component of the teaching and learning process (rather than a concluding stage); it focuses on the learning process (rather than just the product); it tests understanding and thinking (rather than rehearsal and memory); and it is related to teamwork and the individual's contribution to the team. A dialogue takes place between teacher and pupil about the goals of assessment, the manner of its performance, and its conclusions. A learner's reflection about learning is a significant component of his/her success. And portfolio assessment is a major component of many alternative assessment methods.

A portfolio is a record of a pupil's learning process: what a student has learned and how he or she has gone about learning; how he or she thinks, questions, analyzes, synthesizes, produces, and creates; also, how one interacts intellectually, emotionally, and socially. Important ingredients of the portfolio are the learners' reflections at different times, the progress in their development, and future goals. This metacognition or "thinking about thinking" enhances what they learn since learners are often not aware of their internal thinking processes. Through reflection they think about their learning processes, learn to direct their own thinking, and subsequently plan their learning processes.

The Research

Objectives

This study explored:

1. The process pupils undergo while accumulating and completing their portfolio as an integral part of their technological project.
2. The role of one's portfolio for fostering higher-order cognitive skills.
3. A methodological scale for assessing pupils' creative thinking based on their portfolios.

Method

This study was part of a comprehensive study aimed at investigating the impact of project-based technology studies on pupils' self-confidence, self-image, motivation to learn, thinking competencies, and academic achievements (Barak & Doppelt, 1998). Data were collected during ongoing work with the pupils, using documentation of class activities; discussions; informal talks or semi-designed interviews with pupils, parents, other teachers, and school staff; copies of pupils' portfolios; and examples of their projects in different stages. This article focuses on the process of developing and assessing pupils' portfolios.

Subjects

The subjects of the study were 10th-grade pupils in a high school in northern Israel. The intervention program ran from 1994 to 1998. Fifty-six pupils participated in this program (9 to 24 pupils each year). All pupils had profiles of low academic achievement at the end of junior high school and most were deemed inadequate for studies at the level required to receive a matriculation certificate upon graduation from high school.

Intervention

The program, entitled "Creative Thinking and Technology" (Barak & Doppelt, 1998), encompassed two hours of study each week during an entire school year. During the first semester of the school year (about 15 weeks), the class learned thinking tools from the CoRT thinking program developed by De Bono (1986, 1994). Thinking tools such as PMI (Plus, Minus, Interesting), CAF (Consider All Factors), and APC (Alternatives, Possibilities, Choices) were studied.

After drawing on examples from the pupils' daily lives, learning focused on the process of constructing mechanical systems, such as a car or a robot, by means of the LEGO-Logo system. For example, all pupils constructed identical cars according to a given LEGO design, compared their features, and suggested improvements while using the CAF and APC thinking tools. In the course of this process, the pupils also became familiar with the LEGO-Logo system and the computer interface and with writing basic programs in the Logo language.

During the second semester (about 15 weeks), the pupils chose and performed original technological projects; for example, a robot that moved in forward or circular motions and cleared obstacles on the floor; an automatic conveyor belt that received, identified, and counted items loaded off a truck; a crane that scanned an area, collected objects that were randomly distributed, and delivered them onto a train; and a chocolate drink machine that filled powder into a glass, mixed it with milk, and delivered the glass onto a conveyor. The pupils coped with complex problems and found solutions that depended on creative thinking by synthesizing lateral and vertical thinking.

Data Collection

Pupils constructed 35 portfolios over the five years of the program. The difficulties they encountered while solving their problems, designing the construction, and programming the computers, and the teacher's hesitations about how to deal with various situations (such as how much to interfere or help with the pupils' work) were all documented.

Results

Process of Constructing a Portfolio

Assessment methods. After the pupils had experienced the application of thinking tools from the CoRT series while designing and constructing computerized systems in a LEGO-Logo environment, a discussion occurred at the end of the first semester, prior to the second semester. The teacher introduced the pupils to the following new principles for assessing their work: assessment refers to the work process and not just the final product; both peer assessment and self-assessment would take place; and the final grade would be awarded cooperatively by the teacher and pupils, according to predetermined weighting. The teacher and pupils cooperated in preparing examples of elements that may enter a folder, including sketches, drawings, calculations, flow charts, computer programs, photographs of the models in various stages of development, the thinking process that led to the model's design, the problems encountered by the pupils, and how they managed to overcome the problem.

Since the students were accustomed to receiving grades for turned-in assignments, it was hard to explain the value of drafts, documenting the difficulties they encountered, as well as the purpose of photos or sketches of initial models. To convince them that continuous documentation of their work was necessary, the teacher presented them with final models of pupils' work from previous years, along with the portfolio prepared by the pupils. Thus they saw that sometimes the final product was completely different from the first model. Previewing portfolios along with finished projects illustrated how previous pupils sometimes encountered complex problems that they managed to overcome. Pupils were persuaded that the final model alone without documentation of the different stages does not give an opportunity to see the design and construction process, the efforts invested by the pupils, and the pupils' achievements. Despite this, the pupils were not easily convinced, and each year the same question arose: "Why is it necessary to document all stages of the design and construction process?"

Weighting of the portfolio elements. About three weeks after the pupils had chosen their project topics, a class discussion took place, during which the pupils formulated the criteria for assessing their work and the weight of each criteria in the final grade. Table 1 reflects the pupils' lateral thinking (such as originality and creativity) and vertical thinking (such as usefulness, quality, and complexity). Criterion 7 reflects high-level skills in both vertical and lateral thinking to achieve a high performance level.

Teamwork and peer assessment. The teacher fostered an atmosphere of teamwork, knowledge sharing, and reciprocity in class. The richness and flexibility of the learning environment allowed each group to begin work on the project from a different point: planning, construction, calculation, or programming. As a result, some of the pupils acquired more knowledge or expertise in certain areas than other pupils. This created a basis for true cooperation, information transfer, and reciprocal help in problem solving among the pupils. Sometimes a pupil from one group would help pupils working on a different project. As a result, the pupils were familiar with their peers' work, the difficulties they had overcome, and the

Table 1. An Comparative Example of Peer and Teacher Assessment.

Criteria in Portfolio of Group 1	Weight	Group 2	Group 3	Group 4	Group 5	Teacher
1.Originality	10%	9	8	8	10	10
2.Usefulness	25%	24	18	23	20	24
3.Considering all factors	15%	10	10	9	10	12
4.Computer program feasibility	20%	19	18	18	20	19
5.Technical quality, graphic editing and design	10%	6	7	7	10	6
6.Interesting subject	10%	8	7	7	10	7
7.Complexity – number of subsystems / procedures	10%	4	7	5	10	5
Total	100%	80	75	75	90	83

efforts invested by each one. This made peer assessment more valid. One year, the pupils decided that the weight of peer assessment in the final grade would be 70% while that of the teacher's assessment would be 30%. At the end of the school year, the pupils presented their work to their peers. They prepared a presentation that summarized their work in retrospect, reconstructed their management of difficulties, and demonstrated special achievements. This event also served as the formal stage of peer assessment. An example of peer assessment scores is also shown in Table 1.

The scores reported in Table 1 show a high internal consistency among peers' and teacher's scores (reliability coefficient alpha = 0.987). This indicates that the pupils and the teacher reached a strong consensus. In this example, the final grade was 81% (70% the average score of the four groups of pupils and 30% the teacher's score).

Discussion

Two Domains for Assessing Creative Thinking

In analyzing the pupils' portfolios, two domains stood out in assessing the pupils' creative thinking. The first domain relates directly to the development process of the product or the system planned and constructed by the pupils. Higher order thinking levels were expressed in the portfolios, for example, by describing unique system features, findings of conducted tests, performance attained in comparison to the original plan, difficulties the pupils encountered, and how they managed to overcome them. Examples of lower order thinking levels include a standard schematic diagram (taken from a book, for example) or a basic explanation about the purpose of the system and its mode of action.

The second domain relates to pupils' thinking and learning processes, teamwork, and cooperation in class. Pupils who reach a high level of lateral and vertical thinking may express these processes in their portfolios. They can mention, for instance, their hesitation in choosing among different alternatives while planning or problem solving, how they shared their work among themselves, or how they turned to members of other groups for help. Also, learners are not always aware of their internal thinking processes. But, constructing the portfolio caused pupils to reexamine the processes they went through. Pupils who reach higher order thinking may illustrate in the portfolio the manner in which they used the thinking tools they learned.

Developing an Assessment Scale

After identifying the above-mentioned domains for characterizing the level of creative thinking on the basis of the portfolio elements, we developed an assessment scale of the creative thinking level achieved by the pupils, based on the elements they included in their portfolios. De Bono (1996) defined four achievement levels of creative thinking skills development:

> *Level 1: Awareness of thinking.* General awareness of thinking as a skill. Willingness to think about something. Willingness to investigate a particular subject. Willingness to listen to others.
>
> *Level 2: Observation of thinking*. Observation of the implications of action and choice, consideration of peers' points of view, comparison of alternatives.
>
> *Level 3: Thinking strategy*. Intentional use of a number of thinking tools, organization of thinking as a sequence of steps. Reinforcing the sense of purpose in thinking.
>
> *Level 4: Reflection on thinking*. Structured use of tools, clear awareness of reflective thinking, assessment of thinking by the thinker himself. Planning thinking tasks and methods to perform them.

Table 2 offers characteristics of portfolio elements for each level in the two domains: (a) system or product design, construction, and evaluation, and (b) learning and thinking activities.

The scale presented in Table 2 is clarified below, including several genuine examples from pupils' portfolios.

> *Domain A—Level 1: Presenting a system pictorially accompanied with basic explanations.* This kind of documentation is graded relatively low on the creative thinking scale since it expresses mainly the pupil's awareness of the need to present his or her work before others, labeling its parts, and providing basic explanations.
>
> *Domain A—Level 2: System documentation by schematic electrical or mechanical drawings and computer programs.* This type of documentation is ranked at the second level of the creative thinking scale since the pupils have to show how they observe the implications of choice, such as using specific components or programming algorithms.
>
> *Domain A—Level 3: System outline by block diagram and flow chart structural tree chart.* These elements of the portfolio correspond to the third level on the creative thinking scale entitled "thinking strategy," since the pupils must choose a strategy and coordinate among various explanations in their work. They have to decide what level of detail is required and how to present the sequence of action or logical conditions of the system's action. Pupils reported it was easier for them to build a system or write a computer program than to describe their work using systematic flow charts or block diagrams.

Additional portfolio elements at this level include a description of the number of iterations and problem solving.

> The machine is controlled by time, but it has a number of problems…the glass gets stuck or goes too fast and thus the mixer does not come down in time…we added a sensor which controls the action of the mixer…the machine started to act as required.

This example shows that the pupils had independently discovered one of the basic principles in the action of control systems: feedback control is preferable to open-loop control.

In the portfolios of the wind turbine project, we found the following statements:

> After changing our machine many times we succeeded to produce 3 volts. But we knew that we needed more power so we sat together and thought how to improve our machine. One idea to increase speed was to build wider wings. The other idea was to change the mechanical trans mission. We decided to work on both ideas and the result was very good; we produced 6 volts this time.

This example shows reflection upon the whole process and the problem the pupils had in terms of planning and constructing the optimal model.

The following passage appeared in one pupil's portfolio:

Table 2. A Creative Thinking Scale Derived From Portfolio Elements of Technology Projects

Portfolio Domain	Level 1 Awareness of Thinking	Level 2 Observation of Thinking	Level 3 Thinking Strategy	Level 4 Reflection on Thinking
A. System or product design, construction, and evaluation Originality, authenticity, usefulness, unique design (lateral thinking products). Functionality, reliability, accuracy, geometric structure, scientific principle (vertical thinking products).	Standard diagram of a system or product taken from available literature. Basic explanation of the model and its construction. Description of the model by means of pictures or sketches. An example of solving a simple problem in planning and construction.	Original schematic diagram of system or product designed by the pupil. Detailed drawings of the model. Specification of planning and construction stages including calculations, specifications, or computer programs. Justified examples of choices among a number of alternatives.	Original system functional block diagrams, structural tree, or flow chart. Description of a number of iterations in the planning and construction of the model. Comparison among and choosing from a number of models.	Examination of the final product's features, compared to the set goals. Conclusions on successes or difficulties during the development process. Suggestions for improvement in the planning and construction process.
B. Learning and thinking activities Individual and group efforts in project development and problem solving. Processes of teamwork decision making and leadership.	Division of tasks in the team. Few examples of using lateral and vertical thinking tools.	Information exchange and reciprocal help in the team. Various examples of using thinking tools.	Examples of the contribution of individuals and teamwork to solving complex problems. Evidence of planned use of the thinking tools, open-mindedness, and postponing decision (lateral thinking); setting priorities, goals, and criteria (vertical thinking).	Conclusions drawn from the influence of the team's functioning on the completion of the project. Pupils' views on the influence of the team's functioning on thinking and learning processes. Assessment of the selected solution compared to the goals.

> One pupil concentrated on programming, drawing preparation, and the functional description, while the other pupil was responsible for constructing the model and the mechanical calculations.

In another project, the pupils wrote:

> To maintain a certain working order, we decided that each of the group members will work on a different part of the system. Of course, everyone will also have the right to make suggestions and improve parts on which he isn't working personally.

In this example, the pupils spontaneously used the PMI (Plus, Minus, Interesting) thinking tool, taken from the CoRT program, studied six months earlier.

> The mechanism that moves the digger is the most complicated part of the project. We encountered the problem that the track would move very quickly. The positive side of this: everything went faster. The negative: the tractor would fall apart because of the great speed. What was interesting was that the motor had a strong power to move the lever quickly, and thus we decided to change the transmission coming from the motor to the track.

The two highest levels in Domain B on this creative thinking scale manifest themselves in the portfolio as examples of using thinking methods to solve complex problems, how teamwork affected their work, or how decisions were made by the team. Only scant and indirect references to strategy and reflection-thinking processes in the portfolio were, in fact, observed. In the portfolio, the pupils reported retrospectively what had been achieved over weeks and months. The difficulties encountered were mentioned only briefly, although pupils invested much effort and made several attempts prior to reaching the described solutions. Sometimes the pupils encountered periods of crises and despair or, conversely, periods of enthusiasm and working late at night, but this was not generally documented. The pupils directed much more attention to describing the system they constructed and its features (Domain A), since they perceived this as the main task, rather than their reflection on the process itself.

One Project:

A team of three pupils built a machine aimed to squeeze large-size junk into a small piece. The pupils' portfolio was comprised of a description of the machine, the process of design, construction, programming, and improvement, as shown in the following authentic examples.

- Example 1: Machine description.

> The machine contained five subsystems, as seen in Figure 1.

Pupils' explanation of their system:

> A loading truck: carries the junk to the conveyor at the reception station. Download is assisted by a pneumatic piston
>
> A conveyor: moves the junk to the robot station.
>
> A robotic arm: moves the junk from the conveyor to the squeezing station.
>
> A squeezing machine: presses the junk by means of four pneumatic pistons.
>
> An uploading fork: takes the compressed junk out.

- Example 2: System structure presented by a tree chart.

The pupils' portfolio contained a chart of the machine structure.

This kind of chart is original and shows pupils' understanding of the system structure and functioning.

- Example 3: Computerized control - A Logo program.

Part of the system was controlled via the LEGO-Logo interface and programming language. An example of a computer Logo program is demonstrated below.

```
To start: key
    Listen-to [sensorA? sensorB]
    If sensorA? [stop]
    If sensorB? [stop]
    If (ascii :key) = 328 [motorA-right]
    If (ascii :key) = 336 [motorA-left]
    If (ascii :key) = 333 [motorB-right]
    If (ascii :key) = 331 [motorB-left]

    If (ascii :key) = 139 [graphic]
    If (ascii :key) = 138 [go-forward]
    If (ascii :key) = 137 [go-backward]
    If (ascii :key) = 136 [auto-program]
Start read-char
End
```

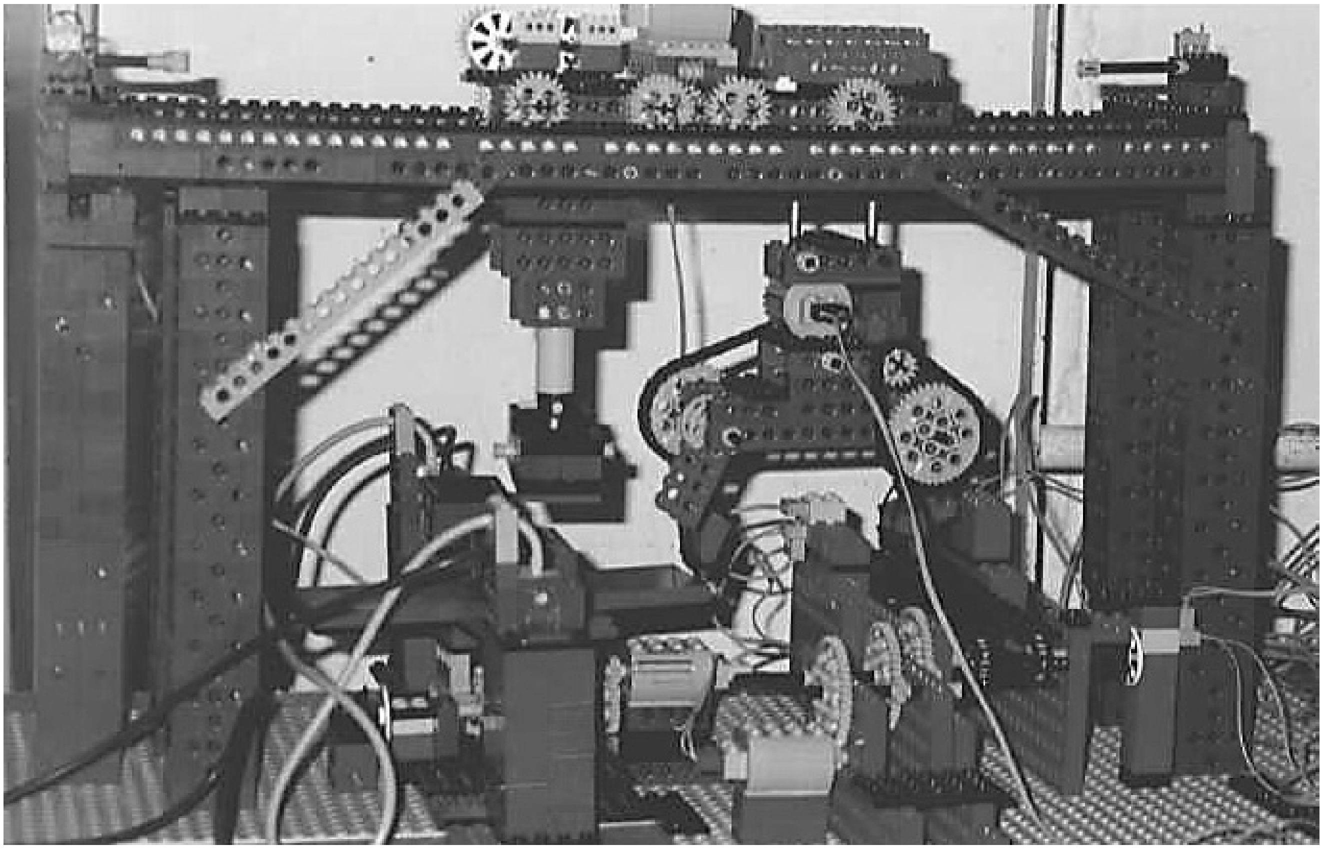

Figure 1. A machine description: A computerized machine for squeezing junk.

The program demonstrates structured programming. In every row there is a specific procedure such as "motorA-right."

- Example 4: Functional block diagram.

The pupils used an industrial programmable logic controller (PLC) to control the robotic arm and the electro-pneumatic valves.

- Example 5: Technical planning.

An important part of the pupils' work was technical calculations and computerized drawing of the parts and subsystems.

The above five examples demonstrate different aspects of pupils' work on the technological project. Table 3 provides an assessment of their work using the CTS.

Finally, most of the portfolio elements at the end of 10th grade correspond to Levels 2 and 3, although occasionally Level 4 elements and level elements were present. In a conventional learning situation, De Bono (1996) expected an average achievement between 1 and 2, and in learning that stresses thinking development, an average achievement between 2 and 3 should be expected. A higher rate of items in Levels 3 and 4 was found when the pupils continued their projects in the 11th and 12th grades. The achievements of the pupils in this study are particularly significant, since they were considered low achievers at the onset of their high school studies.

Conclusions

In view of the growing influence of technology on the individual and society, technology education is increasingly becoming an integral component of education for all age groups. This study highlighted the role of portfolio assessment in technology education and its contribution to promoting higher order thinking skills in school graduates. The perception of creative thinking as a synthesis of lateral and vertical thinking emphasizes the cognitive implications of technology education and, in par-

Table 3. Examples of Methodological Assessment of Portfolio Elements Through the Creative Thinking Scale (CTS)

Portfolio Element	Rank on CTS	Interpretation
Example 1: Machine description	1	Description of a system by a picture and listing of system components is ranked low on the scale. However, this kind of documentation is recommended.
Example 2: Presenting system's structure by a tree chart	3	An authentic structural tree of a technological system is ranked relatively high on the scale because it demonstrates pupils' ability to utilize system approach and present their unique design intelligently and insightfully.
Example 3: Computerized control—a Logo program	2	Although the given example shows original programming, using subroutines, it provides specific solutions and concrete system's operations.
Example 4: Functional block diagram	3	The original functional block diagram shows how the pupils understand and apply the three basic functions of a feedback control system: measuring, comparing, and correcting the controlled variable.
Example 5: Iterations in technical design	3	A display of systematic iterations of technical design is graded higher than simple use of given formulas.

ticular, project-based learning. Technology presents many opportunities for promoting imagination and a wealth of ideas and for developing new products to fulfill human needs and realize human aspirations. Dealing with these issues at school may engender growth in lateral thinking skills. However, realization of the ideas, turning imagination into reality, designing and constructing instruments or systems that perform the expected function and fulfil the requirements of quality and reliability necessitates the activation of mathematical-logical tools, knowledge of laws of nature, systematic planning, and consideration of limitations and constraints. These require more vertical thinking. Lateral and vertical thinking complement one another, and technology education via projects constitutes a basis for experience in, and the promotion of, both types of thinking. This perspective necessitates changes in educational perceptions and curriculum planning. For decades education has stressed vertical thinking over lateral thinking, particularly in mathematics and science studies.

However, fulfillment of the existing potential in technology education for promoting higher order competencies does not happen spontaneously. This study shows that introducing "thinking lessons" into technology curricula helps to develop an awareness of thinking among the teachers and pupils and gives them new tools for observing, thinking, and reflecting on thinking. Emphasizing the promotion of thinking processes within technology education should also express itself in assessment methods at school. Traditionally, teachers and pupils engaged in technological projects directed most of their efforts to completing the task and documenting the final product. While preparing a portfolio, pupils are encouraged to express the wealth of means they used, modes of action adopted, and the processes that the pupil and team go through during designing, constructing, and improving the technological system. Pupils do not tend to keep records of their work, document their experiments, or report their difficulties. Thus, it is essential for the teacher to discuss and cooperate with the pupils in determining the criteria for assessing their work.

The suggested assessment scale of creative thinking can help educators strive for a gradual development of higher order thinking skills in two main areas. The first is choosing the project topics for the pupils, their complexity, level of expectation for originality and creativity on the one hand, and the extent of using mathematical-logical and scientific thinking on the other hand. The second area of gradual progress is developing learning and thinking processes in class, problem solving, teamwork, and reflection on thinking. Thus, learning through technology projects based on portfolio assessment and directed towards a systematic development of vertical and lateral thinking may promote teaching and learning that assist the school graduate's successful integration into a dynamic and changing world.

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Perspectives From a New Department Chair

Jack W. Wescott

After three challenging and exciting years as a new chair, I am presenting the following thoughts—some perhaps profound, but the majority quite trivial about my perceptions of a new chair. Many of my comments presented are based on informal observations; however, there was an opportunity for me to review the research about the roles and responsibilities of the department chair in higher education. For organizational purposes, this paper is organized into the following sections: the importance of chairing a department, characteristics of chairs, preparation for becoming a chair, and the often-conflicting management and leadership responsibilities.

Importance of Chairing a Department

> The chair job is the most difficult on campus in many respects. First, the continuous need for attention to details, second the need to make decisions which have an impact on the lives of those with whom you also deal on a personal basis, and third, when things go wrong the chair carries directly or indirectly a good share of the responsibility. (Bennett, 1982, p. 52)

Few would argue that chairs are important in the overall academic leadership team on campus. As early as 1942, the chair was characterized as the key position in a department and in the institution (Jennerich, 1981). Furthermore, an editorial in *The Journal of Higher Education* noted that "no one plays a larger part in determining the character of higher education institutions than the department chair" (Patton, 1961, p. 459).

A recent advertisement in the *Chronicle of Higher Education* (April 4, 1997, p. B96) announced a nationally respected leadership program for department chairpersons by terming them "the people responsible for leading the units where change takes place in higher education." This statement eliminates any doubt about the importance of the position. Further, department chairs make up possibly the largest administrative group in U.S. colleges and universities (Norton, 1980). In 1997, Scott reported that an estimated 80,000 department chairs were involved in higher education and one in three faculty serves in the position at some point during his or her career.

A summary of the research on the importance of chairing an academic department identifies three key factors. First, chairs have daily contact with administrators, faculty, and students (Weinberg, 1984). In most administrative hierarchy of an institution, chairs are directly responsible for the department's daily operations. Waltzer (1975) identified chairs as the "single most important link" in the campus structure between administrators, faculty, programs, and students. This link serves as the conduit through which intentions of top management flow down and information flows up. As such, the chair often serves as negotiator between departmental goals that reflect institutional priorities and the individual goals and agendas of faculty and students.

Second, on most campuses, the chair has the authority over matters that are important to the faculty and staff: curriculum, budget, faculty hiring, and evaluation. The chair is the "custodian of academic standards" charged with monitoring the department curriculum, seeing that course assignments are made judiciously and that individual faculty members' talents are aligned with instructional needs, promoting racial and gender balance in the faculty, encouraging continued personal and professional growth, and attesting to the adequacy of instruction and research (Bennett & Figuli, 1990).

Third, chairs serve as important decision makers. From the perspective of a new chair, there are some unique attributes associated with the decision-making process in a department that I would like to share. For example, immediately on being named to the position, everyone expected me to be intimately familiar with all the practices, policies, and procedures throughout the university. One morning, for example, three phone calls sought answers to each of the following questions: "Are the new regulations under the Immigration Reform and Control Act of 1992 applicable to one-year temporary faculty?" "What is the distinction between Category I and Category II graduate faculty status?" "What is the maximum hours per week that a faculty member can consult outside the university?" It soon became obvious that there is a great deal of information about the university of which I was not aware.

Everyone also assumed the chair possesses unlimited power and authority to solve any and all problems. Generally speaking, faculty, staff, and students do not understand that all kinds of checks and balances exist within the academic community. Aside from one's own conscience and the matters of academic freedom and integrity, there are policies to follow at all levels. Making a decision that is contradictory to the established guidelines is always unwise and sometimes illegal. It also appears that there is an inverse relationship between the importance of a decision and the amount of time you have to make it. That is, important decisions seem to be due tomorrow and those less important decisions are due at the end of next month.

It is also important to learn "when" and "if" a decision must be made. Many problems will go away if a decision is postponed. Of course this is an oversimplification and not recommended as good practice. But the fact remains that some problems simply go away. Example, a faculty member would confront me in the hallway about an urgent problem. (By the way—I have learned to never make a decision in the hallway or, even worse, the restroom.) The faculty member would make an appointment to see me regarding the urgent situation. Then, moments before the meeting, I would receive a phone call indicating the situation had been resolved and the appointment cancelled.

Characteristics of Chairs

Generally speaking, the academy offers no clear line of succession for becoming a department chair. While some large departments may have an assistant or associate department chairperson, this position is not the norm. Moreover, even having such a position does not mean that the person holding that title, and therefore assumed to be gaining some acquaintance with the roles and responsibilities of the chair, will be appointed to the position when it becomes available. There are many reasons why an individual is ultimately elected or appointed to the position, but preparation and base of skills and knowledge are not always two of them.

According to research conducted by Carroll (1990), the typical career path for a department chair begins within an academic discipline as a graduate student, then as faculty in the same discipline, moving up through faculty ranks, and eventually becoming the department chair. Stepping into the role of chair occurs when faculty are in their middle to upper 40s (e.g., 46 in Carroll, 1990; 48 in Boice & Myers, 1986). Chairs serve on the average of six years, and 65% return to faculty status immediately after their service (Carroll, 1990). Similarly, Hecht, Higgerson, Gmelch, and Tucker (1999) determined that the nationwide turnover rate for chairs is 15 to 20% per year, with the term of service usually running six years. Female chairs are significantly younger than their male counterparts when they take the position and are more likely than males to become a department chair before receiving full professorship (Carroll, 1990). In our profession, it is important to note that according to the *Industrial Teacher Education Directory* (Bell, 1999) there are 12 women chairs, coordinators, or leaders for the 210 institution listings, which translates to approximately 5.7%.

Lack of preparation

Regardless of gender, individuals assuming the position of chair experience abrupt changes in their work life, adding to the strains and stresses of academic life. Facing these roles is compounded by the fact that chairs come out of the ranks of faculty in disciplines that might be far afield from management and leadership. The problem is also magnified because most chairs have no formal preparation for the position. More frequently than not, the chair's position is filled by an individual who is likely to be unprepared for the tasks. Also, Gillespie (1998) noted that very few set out to become a department chair, or at least few will admit that is a professional goal, and there are few programs in place for the training of new chairpersons.

> Usually, regardless of how the decision is made, chairs are not chosen because they are good administrators, managers, leaders or communicators. This isn't so much an indictment of higher education as it reflects a simple fact: Most academic administrators, especially at the department level, are educated on the job. (Hickson & Stacks, 1992, p. vii)

Although universities have recently begun to be attentive to the need for preparation for the teaching role in higher education, there is still a need for similar programs to address the issues of chairing a department.

Managing Versus Leading

One of the greatest challenges that most new department chairs face is balancing the management and leadership responsibilities. "Chairs, like the god Janus, have two faces: a manager and a leader" (Gmelch & Burns, 1991, p. 4). A number of writers have addressed the real and implied definitional distinctions between managing and leading. In an article on organizational leadership, Bennis (1980) suggested that managing and leading differ in a number of ways. Leaders are involved in activities of vision and judgment while managers engage in activities of efficiency. Managers engage in the day-to-day conduct of the organization while leaders transcend the everyday organizational routines to guide the organization.

Most new chairs bring a variety of new ideas, goals, and a sense of vision to their position. These ideas are ones that may guide the department through the chair's term of office and beyond. They constitute the impact that the new chair hopes to have on his or her department, the mark he or she will leave. As such, these innovations and creative ideas fall most clearly within the boundaries of leading rather than managing. However, out of necessity it is the managerial role that the chairs learn first. In addition, the managerial procedures related to travel, promotion and tenure, merit pay, accreditations, campus governance, and budgets often receive priority. These items tend to constitute the everyday work of the chair, the efficient conduct of the department in relation to the larger university.

Actual leadership, taking new directions and implementing a vision, tends to come later in the chair's tenure. New chairs must learn to manage successfully before they can effectively lead within the university system. The ability to communicate wisely and well is the key to the Janus-faced roles of the academic chair. Despite the unusual management structure in which they find themselves, chairs still exert considerable influence on program direction and personnel development within their academic units.

Chairing a department revolves around three highly interrelated factors. First, chairs have daily contact with administrators, faculty, and students. Second, chairs are important decision makers. And third, on most campuses the chair has the authority over matters important to the faculty and staff. Furthermore, one of the most significant challenges that most new chairs face is balancing the management and leadership responsibilities of an academic department. As a new chair, it appears that the leadership or visionary role of the chair is often diverted by the numerous details of management responsibilities. However, despite the mirage of management duties, it is the leadership role that is critical to addressing the important issues of the profession.

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Making Total Quality Management + Just-in-Time Manufacturing Work

Phillip S. Waldrop and Thomas E. Scott

The competitive benefits of just-in-time (JIT) manufacturing, including the key elements of cellular production along with empowered teams, are well documented in both academic and trade literature, such as in Costanza (1994), Deming (1982), Lahidji (1997), and Richardson (1997). Studies on these topics typically focus on benefits, management theories, and technical aspects of JIT. But to maximize success one must also consider the individual person who works in the newly modified environment.

Shop-floor personnel considerations differ considerably from those involved in more traditional manufacturing organizations ("Self-Directed Teams at XEL," 1993). As described by Salas and Cannon-Bowers (1997), contemporary technical management methods often reflect change in culture more than technology. These cultural differences go beyond the basic need to cross-train personnel in the multiple process skills of a cellular operation. Certain practices must also accompany a successful shift to JIT. All the finalists for a leading industry magazine's annual Best Plant Award ("Lessons from the Best," 1996) included these features:

- Employee empowerment.
- Employee problem-solving teams.
- Self-directed work teams.
- Financial rewards for team-based performance.
- Employee involvement in benchmarking.

Simply being aware of total quality management (TQM) and JIT buzzwords is insufficient to make it happen; technology professionals need to know *how* to apply these concepts. In turn, significant changes in industrial technology curricula, especially in technical management courses, need to follow. "Supervision," for example, might be better termed supervision and team building. The following two industrial case studies, conducted in 1997, illustrate essential considerations in building a team environment, including identification of skills needed by team members, new hiring process approaches, training and development approaches, and an incentives approach.

The first case describes the implementation of the team concept in the production operation environment at a newly designed and constructed facility. The second case describes the implementation of the team concept in the product development/product engineering function, an application of the team concept in an *ad hoc* project rather than in mainstream production. (At the request of their management, the firms are represented here with pseudonyms and are pointedly not listed in the references.) Both cases illustrate how TQM and JIT manufacturing work in typical work settings.

Case One: MTC

The first firm, MTC, recently expanded its historic focus on smaller play products into larger-scale items such as plastic tricycles, playhouses, and other outdoor play equipment. Requiring additional capacity, MTC opted to build a new facility, with startup in 1995. As a "greenfield" operation, it was possible to incorporate the latest available management philosophies and methodologies as well as technical features.

MTC's primary manufacturing process is rotational molding. Large three-station machines are operated by teams that pour powdered thermoplastic into the multiple cavities of the mold, close and clamp the mold, and then—while that "mold" sets in the oven and another is cooling—open the third set and remove the product components. These slide down a chute for minor de-flashing and secondary operations. Products are placed directly into cartons, sealed, and moved by team members to finished goods storage. Additional processes include extrusion blowmolding and injection molding.

This operation is labor intensive, with 12-hour shifts alternating between three days and four days per week. As in any team concept, rewards and incentives must be linked to team output (vs. individual focus). When one team excels at MTC, everyone is rewarded plantwide, which promotes "global team" thinking. But incentive plans alone cannot ensure success in the unique team environment. The MTC workforce is truly multicultural in terms of ethnicity/race, gender, and age. Research, such as described by Brauchle and Evans (1998), indicates that such a heterogeneous group may be more successful than a very homogeneous group. However, it is the firm's management philosophy that such conditions demand that individual team personnel must have certain personal characteristics that foster success. Workers need a strong work ethic, cooperative spirit, flexibility, attention to detail, and communications skills to prosper.

Applicants are screened for these elements through a unique process involving a group interview in which eight applicants are interviewed together. A unique phase of the initial interview process involves a timed simulated activity in which the eight applicants, working as a group but on an individual basis, must build a model log house and "sell" it to management for a fixed price. There are variations in the product specifications and in the quality of materials provided. Materials are "purchased," and flawed materials can be exchanged for free if detected before installation or at a cost if detected after installation. Frustrations set in due to expectations and time limits, and the exercise is halted abruptly. Questions are addressed. Shifting to the next phase, applicants are now encouraged to work together as a team, given suggestions about how to do so, and begin again, yielding notable improvements and insight. Finally, they move on to a simulation involving an actual MTC product, again on a team basis.

Throughout this exercise, the interviewers observe body language, common sense, problem-solving and communication skills, and attention to instructions, quality, economy, and profit, in addition to whether people tend to be "loners" or poor contributors of individual effort. Those applicants who are successfully screened are then invited back for a more traditional interview process. Those hired go through an established series of training sessions including teamwork, conflict resolution, safety, and process skills.

Team leaders receive additional training but no additional pay, and their tasks differ from those people focused on production output. Team leaders concentrate on problem solving, reporting, and coordination. In addition to individual responsibilities, at least one person is trained and partially dedicated to monitoring quality throughout the work cell to enhance customer satisfaction. Both the team leader and product integrity job assignments rotate every four months. Each team creates its own charter, value systems, and other guidelines which impact aspects such as their breaks and job rotation, and also have a direct, shared role with management in defining merit rewards.

What are the results of MTC's unique approach to personnel selection and training for the cell/team environment? The careful selection of applicants who are a "best fit" along with purposeful, tailored training and development has measurable value. Morale is high, and with wages that are simply average for the area, turnover has leveled at about 2% across the first two years of operation. The venture into the market for large outdoor play equipment has been highly successful, having rapidly captured a major market share—now approaching 30%—with this facility as the sole plant dedicated to the product line.

Case Two: NTC

The second firm, NTC, manufactures over-the-road trucks. In 1996 a new product was introduced at the existing production facility: a molded fiberglass and stamped aluminum cab body, representing a substantial departure from prior all-metal fabricated designs. Some apprehension existed in the workforce about the new skills and roles the workers would have to adopt, as well as from the perception that jobs would be lost.

To counteract this anxiety and to encourage an increase in productivity, NTC embarked on an experiment in workforce empowerment. Previously, there were few if any definitive examples of team activity. By forming a planning and implementation team involving the workers who would stay on, management hoped to minimize technical risk and enhance the acceptance of the new processes.

In managing the project, particular attention was given to forming a team with:

- interested, dedicated, and experienced workers;
- an engineering representative;
- a parts scheduler; and
- an employee knowledgeable in automated assembly systems.

Identification of the experienced workers was achieved through reviewing work skills, seniority, attendance, and company loyalty.

One of the most notable of the process changes was the three-dimensional "marriage" of the cab parts which results in the shell of the cab. The new process required a robotic machine that would replace the job of several workers. Similar processes were studied at other firms, and the team individually and collectively produced several ideas that allowed the process to be tailored and optimized for NTC's application. Equipment was procured, delivered, and installed at the plant. Additional workers who made up the pilot assembly group were asked to volunteer for the new product line. Each volunteer was interviewed individually by the core team.

Periodic briefings provided management with an oversight of the activity. A strong, autocratic area manager limited the direction of and influence upon the work group by other managers, permitting relative team autonomy. The team informally selected and developed three key leaders: an arbitrator, a technical expert, and an expert in parts supply. Most decisions and suggestions came from group consensus or deference to the arbitrator. When the process was finally implemented, the remainder of the workforce was invited to observe the team, make suggestions, and ask questions. The team had developed strong ownership in the product and its manufacture. For this firm's environment, the empowerment of the team was a bold but successful experiment.

Conclusions

Personnel considerations are an essential part of contemporary technical management and, in addition to general theory and technical detail, must be included in a systems approach to ensure a holistic, long-term success. These considerations are crucial:

1. Focusing on process technologies and management strategies such as JIT, while important, will not ensure effective implementation.
2. Workforce diversity can prove beneficial as well as desirable, as long as the individuals have personal traits that complement the team environment.
3. While these cases demonstrate the merits of the team concept, they also emphasize that focusing on the selection of an appropriate personnel mix is crucial in yielding any company's hoped-for competitive benefits.

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The Strategic Thinking of Novice Designers: Discontinuity Between Theory and Practice

Malcolm Welch and Hee Sook Lim

Introduction

In two studies we conducted, untutored Grade 7 students produced solutions to a design-and-make task in ways significantly different than ones prescribed by many textbooks and theories about learning to design. We found that novice designers (a) sequence the subprocesses of designing quite differently than the prescribed models, (b) do *not* generate several possible solutions and choose the most effective, (c) make greater use of three-dimensional modeling, (d) use less two-dimensional modeling than suggested by textbooks, and (e) constantly evaluate their design proposal from the earliest moments of the design-and-make process.

The first study addressed the question: What design processes do Grade 7 students who have received no prior instruction use to produce a solution to a design-and-make task? Since the strategies used by these students may have been a function of the particular task and the way it was presented, a follow-up study addressed the question: Is the design process used by novices dependent on the task? This second study provided an opportunity to further investigate protocol analysis as a method for understanding novice designers' strategies. It also resulted in the refinement of a coding scheme to describe design process skills.

This article first describes the theoretical framework used for the two studies and reviews related literature. Next, the methods used to collect and analyze the data are described. This is followed by a discussion of the strategies used by students and how the strategies differ from those in theoretical models of the design process. The implications of these findings for the teaching of design and technology complete the article.

The Centrality of Designing

Much current school work presents tasks to students in a form that assumes there is only one correct way to do it and often only one correct solution. Design and technology education, however, presents tasks that have many possible solutions. Furthermore, it provides students with opportunities to apply knowledge to generate and construct meaning. It fosters the kind of cognition that combines declarative knowledge, the *what*, with procedural knowledge, the *how*. As Kimbell, Stables, Wheeler, Wosniak, and Kelly (1991) pointed out, "there [is] general agreement on certain basic tenets of [technology education]. It is an *active* study, involving the *purposeful* pursuit of a *task* to some form of *resolution* that results in *improvement* (for someone) in the made world" (p. 17). And as Breckon (1995) reiterated, "technology [education] provides that excellent method of learning—learning through doing" (p. 11).

The "doing" in technology education involves using design process skills to design and make an artifact in response to a need. A typical form of design process includes identifying needs and opportunities, understanding and detailing a problem, generating possible solutions, building a solution, and evaluating a solution. This process shares many properties with a general problem-solving model used in the resolution of ill-structured problems (Simon, 1973).

According to Jones (1970), "all [models of the design process] are attempts to make public the hitherto private thinking of designers, to externalize the design process" (p. 3). This is nearly always accomplished by using a diagram to show the steps in the process and the relationships between them. Siraj-Blatchford (1993) noted that "providing a simplified model of the process of design which teachers may adopt heuristically provides for the student what Bruner (1986) has termed scaffolding" (p. 22). Vygotsky (1986) referred to this period—when the teacher does for the student what they are not yet able to do for themselves—as the "zone of proximal development" (p. 33), the gap between what an individual can do alone and unaided, and what can be achieved with the help of more knowledgeable others (Bennett, 1992). For as Schön (1987) pointed out, one of the difficulties for the novice designer is that

> designing is a holistic skill [which] one must grasp ... as a whole in order to grasp it at all. Therefore one cannot learn it in a molecular way, by learning first to carry out smaller units of activity and then to string those units together in a whole design process; for the pieces tend to interact with one another and to derive their meanings ... from the whole process in which they are embedded.... [Nevertheless], it is true ... that design processes may be broken into component parts by strategies of decomposition useful both to practice and to coaching. (pp. 158-159)

Models of the design process are readily available in both the technology education literature and school textbooks, and a number of authors have provided detailed historical accounts of their development (e.g., Johnsey, 1995a; Welch, 1996). A recent model "reject[s] the idea of describing the [design] activity in terms of the products that result from it, and instead concentrate[s] on the thinking and decision-making processes that result in these products" (Kimbell et al., 1991, p. 20). The essence of this model is that ideas conceived in the mind need to be expressed in concrete form before they can be examined to see how useful they are. In other words, "the interrelationship between modelling ideas in the mind and modelling ideas in reality is the cornerstone of capability in ... technology" (Kimbell et al., 1991 p. 21). Yet as Johnsey (1995a) suggested, "the model is ... [purposely] vague about what might be happening at any point in the process" (p. 207), reminding us of Lawson's (1990) observation that, in attempting to describe how designers design, "there is not a great deal of action to be seen ... it is what goes on in the designer's mind which really matters" (p. 24). Perhaps it is because so much of the designer's work is hidden that few studies have attempted to investigate their actual practice. Studies of expert designers (Akin, 1978; Darke, 1979; Eastman, 1970; Schön, 1983) have provided empirical descriptions and models. Recent studies of novice designers at the elementary level (Johnsey, 1995b; Outterside, 1993; Roden, 1995), at the secondary level (Kimbell et al., 1991), and at the university level (Elmer, 1996) are beginning to provide useful insights. Yet an enhanced understanding of the strategies of untutored students would undoubtedly exert some good influence on teaching. Hence the next section of this paper describes a method developed to investigate the strategies used by untutored designers.

Method

Ill-structured problem solving has been investigated using protocol analysis (e.g., Ericsson & Simon, 1984). According to Hayes and Flower (1980), a protocol is "a description of the activities, ordered in time, which a subject engages on while performing a task" (p. 4). In the two studies reported in this paper, verbatim transcripts (from audiotape recordings) of the naturally occurring conversation between students as they were designing and making provided the protocols. Viewing the activity of "designing and making" as a particular form of problem solving allows for the adoption of protocol analysis as a research method in this study. Data were provided through the direct observation of novice designers as well as retrospective interviews with them.

The first of the two studies described here involved ten Grade 7 students working in single-sex dyads. Previous research with dyads (Meyer, 1991) found that while those of mixed gender often do not communicate well or work cooperatively, "the use of single-sex dyads ... encourage[s] students' conversation as a means to make their thinking explicit" (Meyer, 1991, p. 14). Students were required to design and make a solution to a task entitled "Paper Tower." The design brief read as follows:

> Using ONE sheet of 220 mm x 280 mm white

> paper and 100 mm of clear tape, construct the tallest possible tower. You will also be given pink paper. This you may use in any way as you develop your solution. However, NONE of the pink paper may be used in the tower you submit as a final product.
>
> Limitations: There is a time limit of one hour. The tower must be free standing. It cannot be taped to the floor nor to anything else. When you have finished, the tower must stand for 30 seconds before having its height measured.

It is possible that the strategies used by students to generate a design proposal may have been a function of this particular design brief, the way it was presented, and the tools and materials available to produce a solution. To rectify that possible bias, we conducted a follow-up study of eight Grade 7 students, again working in single-sex dyads. They were given two hours to complete a different task using a wider range of tools and materials. Each dyad was given the following design brief:

> The Context: Your parents have invited your uncle, aunt, and five-year-old cousin to visit and stay with you for two weeks. It so happens that your cousin's birthday falls on the second day of the visit. You want to give him/her a birthday present but, unfortunately, you are too short of money to buy one. So you have decided to make something as a surprise. You know that your cousin enjoys playing with toys that move, so you have decided to design and make one. Not only does this solve the problem created by having no money, but it offers the opportunity to give your cousin something really special—a toy you have designed and made. Design brief: Design and make a moving toy that will amuse and intrigue a five-year-old boy or girl.

In both studies the students' designing and making was videotaped and audiotaped. The natural talk between the subjects was transcribed verbatim. A semi structured retrospective interview, conducted with each dyad as they watched the videotape of themselves during the designing and making session, was also transcribed. (For a detailed description of the method used, see Welch, 1996, 1998.)

Transcripts of the natural talk during the design-and-make session were segmented into speech bursts. A speech burst was defined as "a complete portion of text uttered by a subject without interruption from that subject's partner" (Welch, 1996, p. 43). A description of the subjects' actions was added to the right of each segment (Figure 1 shows how students' speeches were translated into design strategies.)

The time at which a change in the subjects' actions occurred was added to the left of each segment, thus allowing calculation of the duration of each period of action. A coding scheme (see Table 1) was used to code actions of the subjects. Those actions coded as designing and making were analyzed using descriptive statistics. This analysis provided the data for "mapping," using an XY scattergraph, the design strategy of each dyad. These maps provided a visual representation of the design process used by each dyad, which permitted a comparison between dyads in this study, between dyads in the two studies, and between all nine dyads and a map of a theoretical model derived from the literature (see Welch, 1996).

Results

Figure 2 represents the strategies used by the five dyads in the first study. The map shows quite clearly the dominance of three-dimensional modeling throughout the entire period when students were developing a solution. Equally clear is the iterative relationship between evaluating and modeling.

The map also shows how little time was spent at the beginning developing a solution by discussion or drawing and how quickly students moved to modeling with three-dimensional materials.

Figure 3 shows the sequence in which Dyad 1 in the follow-up study employed elements of the theoretical model of the design process. It offers a typical example of all four dyads in the second study. The similarities between Figure 2 and Figure 3 are striking, including (a) the large proportion of time devoted to three-dimensional modeling; (b) the small amount of time spent generating alternative solutions, either by drawing or discussion; (c)

15,58	S16:	"Like something that's like strategy and needs thinking so it doesn't get bored. Something."	391 392 393	Discussing possible solution.
16,04	S15:	"Um, so a board game or ..."	395	
16,05	S16:	"Yeah, we could make a board game, but its on a tray, right?"	397 398	Refers to performance criteria contained in design brief.
	S15:	"Yeah."	400	
16,40	S16:	"And he needs to do it by himself."	402	
14,41	S15;	"We could use this stuff."	404	Picks up card. Subjects examine materials.
	S16:	"Like what?"	406	
16,55	S15:	"For the board, but also we could use this, he has on a tray."	408 409	
16,56	S16:	"He has to play by himself though, right?"	411 412	Refers to performance criteria.
17,03	S15:	"..., oh yeah, so I guess let's just make a toy."	414 415	Looks at materials on table.

Figure 1. Sample of a segmented protocol.

the almost immediate move to three-dimensional modeling to develop ideas; and (d) the frequency and consistency with which the developing solution is evaluated.

When the strategy used by each of the nine dyads is compared to a map of the theoretical design process (Figure 4), five significant differences are evident.

First, students' strategies are more complex than suggested by any of the models. They did not work in a linear way through the steps identified in textbook models. Understanding the problem appeared to emerge from an exploration of solutions. Students moved very quickly to solution generation. Students did not appreciate the importance of analyzing and focusing on the problem before "jumping straight to design ideas" (Harding, 1995, p. 19). Modeling was shown to be a complex activity, more accurately described by a model-test-refine-test iteration. This iteration itself appears to act as a source of inspiration for new sketching by Dyad 1. The model was the prototype for solutions. Evaluation occurred not as a summative activity after generating and modeling and building, but as an integral and ongoing activity.

Second, these students did not sketch several possible solutions to evaluate their merits. Sketching played an especially small part in the development of a solution. Nor was sketching viewed as a necessary first step in the development of a solution.

Third, it appears that the preferred strategy for developing ideas is modeling in three-dimensional form (Welch, 1998). Students moved to modeling much sooner than predicted by textbook models. The evidence suggests that novice designers are anxious to begin modeling, even before a solution has been fully worked out. This modeling served several purposes: externaliz-

Table 1. Codes to Describe Designing and Making

Step	Code	Definition
Understanding the problem	RBRF	Reading design brief as given to subjects by researcher
	DERF	Discussing/referring to performance criteria
	DCONS	Discussing/referring to constraints
Generating possible solutions	GEN	Discussing possible solution
	DRAW	Sketching/drawing possible solution
	PMU	Planning the making of a mock-up
	MANIP	Manipulating materials to explore one element of a possible solution
Modeling a possible solution	MMU	Making a mock-up
	RMU	Refining a mock-up: making modifications to current solution
	CMMU	Making a copy of a previous mock-up
	ARM	Checking available resources and materials
	ABAN	Abandon current solution: begin new solution
	PPR	Planning the production of a prototype
Building a prototype	MPR	Making a prototype
	IPPR	Identifying a problem with a prototype
	MODPR	Modifying and improving the prototype in terms of the original need: i.e., making a design change
	EGEN	Evaluating as subjects talk about a possible solution
	EDRAW	Evaluating as subjects talk about a sketch or drawing
Evaluation	TMU	Testing one element of a mock-up in terms of the design brief
	EMU	Evaluating mock-up on terms of design brief
	TPR	Testing one element of the prototype as making continues
	EPR	Evaluating the prototype in terms of the design brief
	RRMU	Recording results from mock-up
	RRPR	Recording results from prototype

ing ideas; providing a method of testing, refining, and evaluating ideas; and stimulating new ideas. Modeling appeared to be an essential stimulus to the ongoing development of ideas.

Fourth, constant evaluation was an integral and ongoing activity while students were designing. Evaluating occurred consistently from the earliest moments of designing.

Fifth, and finally, students in the second study made no distintion between modeling a solution and building a prototype. Except for a brief period of sketching by Dyad 1, the model was the prototype for these students.

Discussion

The results reveal good reason to doubt the efficacy of requiring students to follow any form of a linear or sequential design process model, as found in many textbooks and curricular documents. Our studies revealed that untutored designers do engage in many of the subprocesses of theoretical models but do not prioritize or sequence these subprocesses as suggested by the models. This suggests a need for teachers to explicitly teach process skills that will assist students' designing but which do not impose a strict sequence in which those skills are applied. Recent research by Stables (1997) also noted "the importance of children working in a responsive, rather than a prescriptive, manner when engaged in designing and making" (p. 11). Yet at the same time, as Kimbell (1990) described, students must be provided with a superstructure to begin designing. They must be able to think and work strategically, so when time runs out at the end of a project, they are where they want to be.

Metacognitive skills may be central to students' technological capability. Metacognition is knowledge about

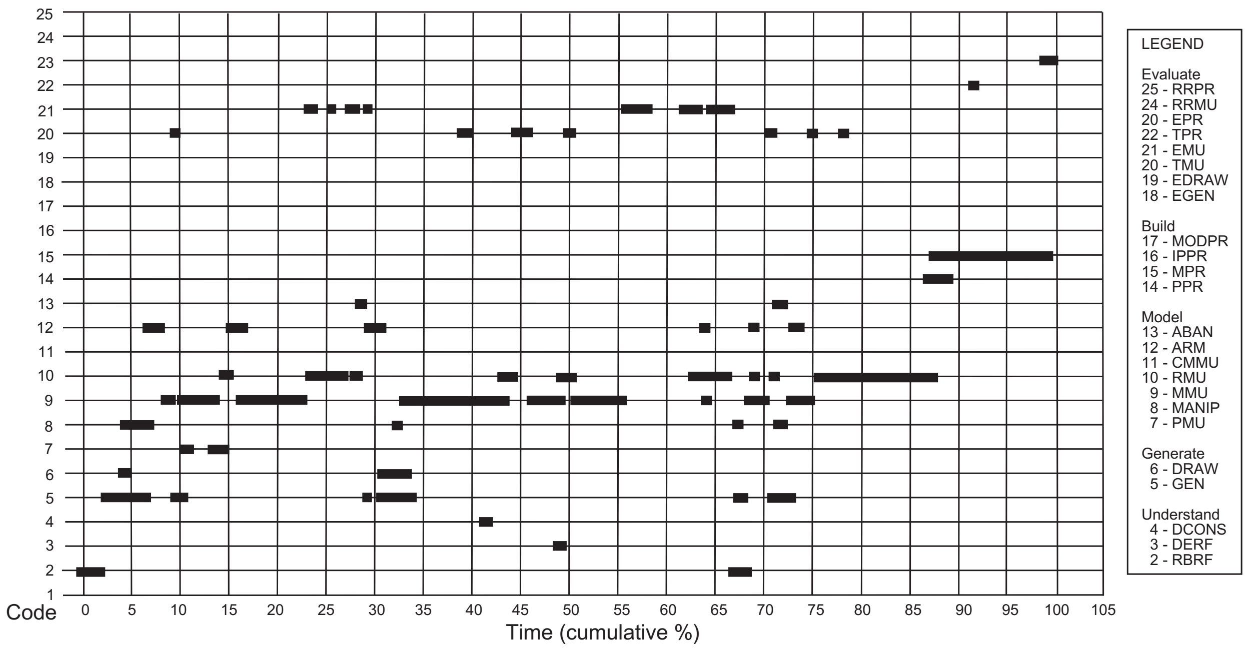

Figure 2. The strategy used by Dyad 5 in Study 1.

thought processes and how to monitor, control, and evaluate one's performance on cognitively demanding tasks (Sternberg, 1994). Most approaches to teaching of thinking and problem solving now put some emphasis on metacognition (Presseisen, 1987). As De Miranda (1998) noted, "technology education ... requires that the learner be highly active in the learning process and exercise considerable control in monitoring [his or her] own progress in accord with metacognitive processes" (p. 15). And Resnick (1987) claimed that if higher order thinking skills are to be an outcome of teaching, instruction must be metacognitively aware and informed. Metacognitively

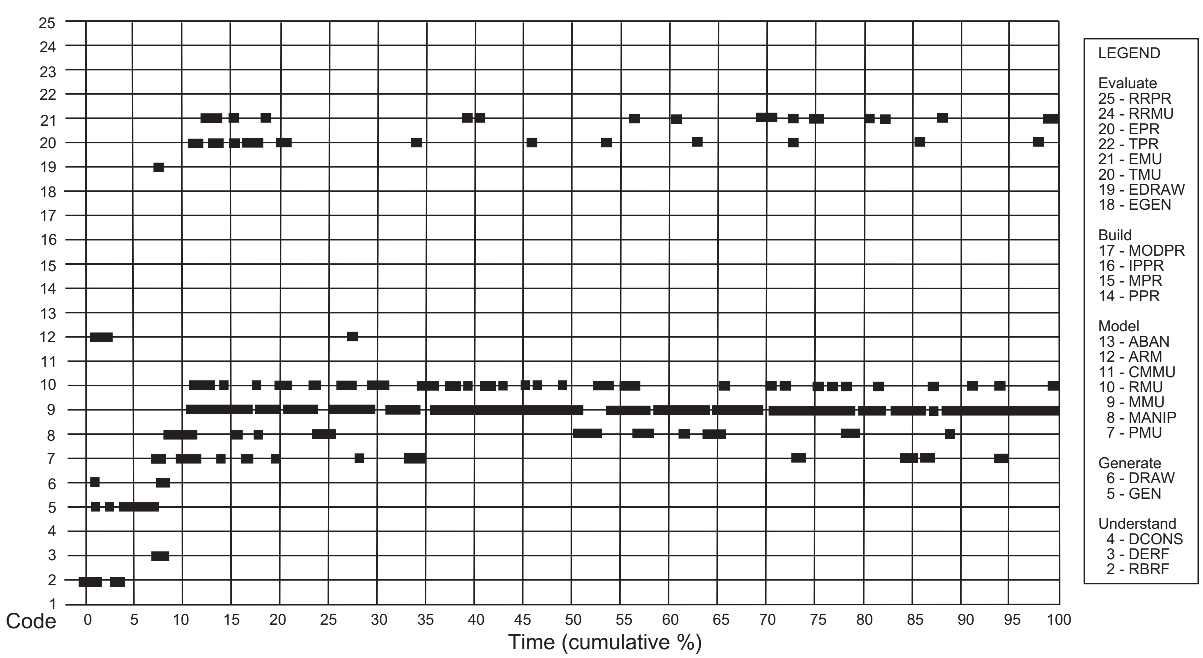

Figure 3. The strategy used by Dyad 1 in Study 2.

aware instruction, according to De Miranda (1998), "attempts to transfer ... cognitive functions ... from the teacher to the student" (p. 2).

Schoenfeld (1987), in a summary of the research on metacognition, identified three related but distinct categories of intellectual behavior associated with metacognition, each of which has importance for teaching and learning in design and technology education:

1. Knowledge about one's own thought processes. How accurate is the student in describing his or her own thinking?
2. Control, or self-regulation. How well do students keep track of what they are doing when designing and making, and how well do students use the input from these observations to guide their actions?
3. Beliefs and intuitions. What ideas about technology (designing and making) does the student bring to the task, and how does this shape the way he or she goes about designing and making?

The first two categories, knowledge about one's own thought processes and control, or self-regulation, are germane to the results of the two research studies reported here.

According to Schoenfeld (1987), students are not very good at describing their own mental abilities. Yet teaching students this metacognitive skill is important. First, good study skills depend, in part, on students' abilities to make realistic assessments of what they can learn because successful designing and making require students to effectively use what they know.

The second aspect of metacognition, control or self-regulation, may be thought of as a management issue. How well are students able to manage their time and effort as they engage in designing and making? This management has several components, including (a) making sure that one understands what a problem is all about before hastily attempting a solution, (b) planning, (c) and monitoring progress while allocating resources wisely as one works on the problem.

In his research with mathematics students, Schoenfeld (1987) showed how the absence of the skill of self-regulation can have "disastrous consequences" (p. 193) when students are problem solving. In Schoenfeld's research, students read a mathematics problem, made a correct conjecture, then made some mistakes and became "bogged down in the calculations" (p. 193). In Schoenfeld's words, "the students ... spent twenty minutes on a wild goose chase" (p. 193).

In a similar way, Dyad 2 in the first study read the

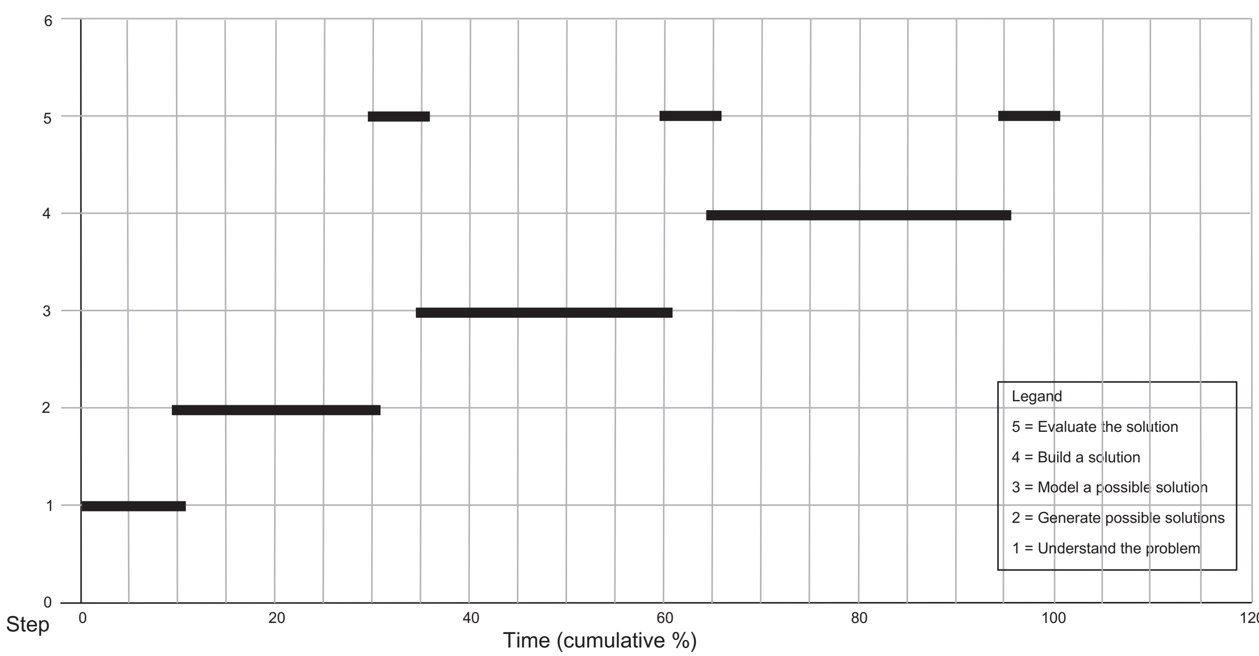

Figure 4. Map of the five-step theoretical design process used in this study (Welch, 1996).

design brief (albeit too quickly to fully understand the task instructions), decided upon a poor solution (using the wrong materials), and then persevered with it to the exclusion of all other possibilities. The result was a failure: a short tower that would not stand for 30 seconds. This failure to successfully create a solution may have been in part because the students lacked the metacognitive skills of self-regulation and monitoring. Teaching these skills would have enabled the students to better access and manage their task-relevant knowledge.

But the failure on the part of Dyad 2 to create a satisfactory solution may also reflect a difference between novice and expert problem solvers. The failure of the solution was in part a function of the rapidity with which the students moved to solution generation. This finding is supported by research on expert/novice problem solving, which has shown that at the beginning of a problem-solving episode, experts spend more time attempting to "understand" the problem, whereas novices move more quickly to solution generation (Chi, Glaser, & Farr, 1988). Novice problem solvers spend far more time doing rather than thinking or planning, neither analyzing the task adequately nor monitoring their own performance. The inability (or reluctance) to consider more than one solution to a design problem is highly problematic. As Bruner (1966) pointed out, "learning and problem solving depend upon the exploration of alternatives" (p. 43).

A second significant result was the critical role modeling (in three-dimensional materials) played in students' thinking. Modeling was used to support a range of activities: increasing understanding of the problem, stimulating the generation of solutions, seeing what a design would look like, testing, and continuously incorporating modifications and improvements into a solution (Welch, 1998). Yet this result contradicts the strategy proposed by most design process models: that students sketch several possible solutions before moving to modeling in three-dimensional materials. Clearly, the results of these two studies suggest that teachers must think carefully about the teaching of two-dimensional and three-dimensional modeling skills. It appears important to provide students, early in the process, an opportunity to explore, develop, and communicate aspects of their design proposals by modeling their ideas in three-dimensional form. Furthermore, a teacher's continued insistence that students generate several design ideas, the "three-ideas paradigm" (Kimbell, 1997, p. 2), may be counter-productive (Hennessy, McCormick, & Murphy, 1993).

In both studies, modeling was seen to be a complex activity, more accurately described by a model-test-refine-test iteration. The following example, taken from the transcript of Dyad 4 in Study 1, illustrates the point.

> Students S7 and S8 had previously rolled and taped one sheet of paper into a single cylinder 280 millimetres tall. S8 began to discuss (GEN) how a single sheet of paper could be cut into two strips, each of which could be rolled into a cylinder before combining the two cylinders:

S8: "You could cut it and then roll 174
half of it and roll the other half and 175
stick it together to make it tall." 176

Her partner agreed:

S7: "Oh yeah, try it." 178

S8 cut the paper into two equal pieces, each 140 x 220 millimetres (Model). Each student then rolled and taped one piece into a cylinder (Model).

S7: "How's this?" 182
S8: "Roll it this way." 184
S7: "Tape the side so it will stay." 186
"Here." 187
"We'll tape the bottom together." 189

S8 then took the cylinder made by S7 and joined the two together (Model).

S8: "Okay, yours is strong so we can 191
stick it, I'll just ..." 192

S7: "I hope it stands. This won't, no, 194
this won't stand up." 195
(Attempts to stand one section - Test)

S8: "... put a little tape." 197

S7: "Okay, will it stand?" 199

S7 attempted unsuccessfully to stand the tower (Evaluate). S8 identified what she thought was the problem:

S8: "I just got to make it even on the bottom."

S8 used scissors to trim the bottom edge of the tower (Refine). S7 made a second unsuccessful attempt to stand the tower (Evaluate). S8 again used the scissors to trim the bottom edge (Refine). The next attempt to stand the tower was successful (Evaluate) and so S7 measured its height (Evaluate).

This example provides clear evidence of a model-test-refine-test iteration. Figure 5 shows the sequence graphically.

The data also show that subjects frequently repeated the test-refine-test part of the loop before returning to modeling. This sequence of activities may be an important aspect of the behavior of untutored designers because modeling appeared to increase students' understanding of the problem, catalyze additional solutions, help refine their ideas, increase exploration of the properties of materials further, and increase students' practice of tool skills.

> This model-test-refine-test strategy parallels that of the *bricoleur* (Levi-Strauss, 1968), the designer who constructs a solution by arranging and rearranging, by negotiating and renegotiating with a set of well-known materials.... The *bricoleur* resembles the painter who stands back between brush strokes, looks at the canvas, and only after this contemplation, decides what to do next. (Turkle & Papert, 1990, p. 352)

The subjects in these two studies operated as *bricoleurs*, beginning with a simple solution and shaping it gradually by successive modifications. If a change did not work, it was undone and replaced with another small change. Schön (1987) captured the richness of this experience when he wrote "designing is a creative activity. A designer's reflective conversation with the materials of a situation can yield new discoveries, meanings, and inventions" (p. 161).

The absence of a distinction between modeling and prototyping by students in the second study indicates the importance of the form in which tasks are presented to students. The task in Study 1 clearly indicated the need to differentiate between a "developing solution" and a "final product." Additionally, different materials were provided for the solution and the product. In Study 2 no such distinction was made. Making was an ongoing part of the process, fully integrated with other design process skills.

The two studies also identified the crucial role evaluation plays as students design. Thus teachers need to stress the importance of ongoing evaluation since it is likely to increase the quality of both the end product and the ability of the student to design effectively. The recognition of a model-test-refine-test iteration so dominant in the strategies used by subjects should, as Johnsey (1995b) has also found, encourage teachers to take a broader view of the nature and role of evaluating when students are designing.

Conclusion

The two studies reported here provide a detailed examination of the strategies used by untutored students working in single-sex dyads to produce a design proposal. Analysis of the data shows that significant differences exist between the strategies used by novice designers and the theoretical models contained in many textbooks and curriculum documents.

The results suggest that teachers must think carefully about the way in which students are expected to explore, develop, and communicate their design proposals, and that teaching any form of linear design process may be counter-productive to students' success in developing a solution to a design-and-make task. The studies also high-

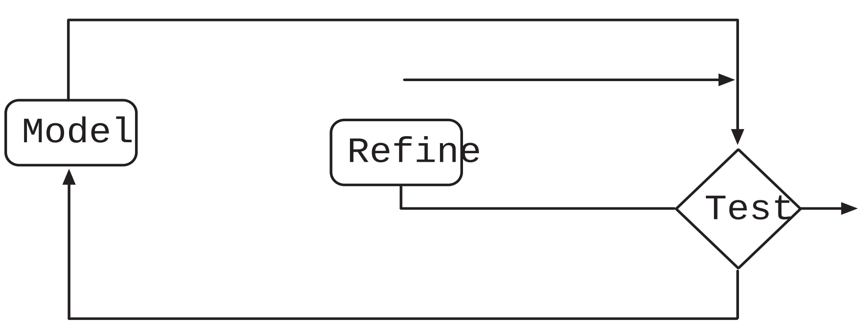

Figure 5. Shows the sequence graphically.

light the need to identify ways in which students can be taught effectively to use metacognitive skills and thus enhance their capability as designers and makers. Teachers also need to consider how the tacit strategies students bring to the design and technology classroom may be used as a foundation for the development of capability. It would be a mistake to discount, ignore, or de-value students' existing knowledge, derived from their everyday experience, of how to design and make.

This article is based on presentations made at the International Conference on Design and Technology Educational Research and Curriculum Development (IDATER98) at Loughborough University and The International Working Seminar for Scholars in Technology Education at George Washington University. Suggestions and comments based on this paper are welcomed and should be sent to the first author at the following address: Queen's University, Faculty of Education, Kingston, Ontario, Canada, K7L 3N6. Tel: 613-533-6000 x77867. Email: Welchm@educ.queensu.ca

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One University's Approach to an Outcome-Based Teacher Education Program

Robert A. Raudebaugh

Since the early 1980s, there has been increasing pressure from both the media and politicians to make major changes in the educational system in America. The impetus for this movement came primarily from the reports of 1983 which led the American public and politicians to believe that our schools were in serious trouble, particularly when compared to those in Europe and Japan. The agitation for educational reform which ensued led to the establishment of more rigorous standards for schools. Eventually the state of Washington enacted the "Washington Educational Reform Act of 1993."

Colleges and universities in Washington are now required to adhere to new standards for teacher preparation. The first of these new standards to be written and adopted was in the area of vocational teacher preparation, which includes technology education. Given no choice in the matter, the questions became, How do we do it? and Can we make it work?

The first step in developing outcome-based curricula was to determine specifically what the outcomes should be. That began with defining what new teachers need to know and what they need to be able to do (teaching tasks) to be successful. Since teaching excellence evolves over a period of many years, the development of teacher education curricula should focus on the skills most needed during internships and the first year.

The technology teacher education program at Western Washington University (WWU) is divided into four content areas: (a) content for technical breadth, (b) content for technical depth, (c) supporting math and science content, and (d) professional or pedagogical content. The process described in this article was limited to the development of (d) the professional content.

Identification of Teacher Tasks/Competencies

In 1991, staff of the Washington Center for Vocational Educator Preparation (WCVEP), including this author, conducted research into the duties, tasks, and competencies related to vocational education, many of which are also related to technology education. A variety of materials were used to identify the tasks including the following:

- The Ohio State University Center for Vocational Education modules.
- Vocational Education Consortia of the States (VECS) modules.
- American Society for Training and Development (ASTD) modules.
- State modules from Florida, Illinois, and Massachusetts.
- Units of instruction for vocational teacher preparation for the state of Washington.

These materials yielded a list of approximately 175 teaching tasks which resulted in surveys administered to vocational teachers and administrators throughout the state. The feedback was used to develop a prioritized list of 80 vocational teacher competencies.

From this competency list and other industrial arts teacher training materials at WWU, a list of competencies for beginning technology education teachers was created. In 1993, this competency list was submitted in survey form to 64 practicing technology teachers and administrators for verification and validation. (The survey participants were selected on the basis of their involvement in the technology education reform movement.) The results were analyzed and used in further developing materials for the professional course structure for technology education at WWU implemented in the spring quarters of 1994 through 1997. To validate competencies in these new areas, a panel of experts identified tasks missing from the current list but required to meet new standards. The panel consisted of the state supervisor for TSA, the executive secretary of the Washington Technology Education Association, and two teachers from local high schools actively engaged in developing technology education programs and in working with student interns. The problem identified at the beginning of the procedure was to determine what effective teachers need to do to work with implementing tech prep and school-to-career concepts, and how to incorporate quality student leadership activities into technology education programs.

The 1997 survey report and the work of the panel of experts were analyzed and the results were incorporated into a final competency list. During the process of determining which competencies belonged to which course, many teaching tasks were reorganized into more coherent groupings under new competency statements. The competencies were then incorporated into the five existing courses making up the professional component of the program.

Development of Instructional Strategies

Development of the outcomes and their organization into a course structure was followed by the selection of the effective learning strategies that would aid students of differing learning styles to successfully reach the desired outcomes. Before instruction began, students were presented with the course competency requirements and informed of the process used to develop them. By so doing, students were found to be more accepting of the competencies and performance standards and the methods used for instruction.

All too frequently teacher educators use a “do as I say, not as I do” approach to methodology in teacher education courses. In order to be effective, teacher educators need to model the behaviors that they expect teacher candidates to eventually use in their classrooms and laboratories, and these classroom behaviors should be incorporated into the learning strategies used for an outcome-based approach to instruction.

General skills (including problem solving, teamwork, and collaboration), such as those recommended in the SCANS Report (1992), and independent information gathering and learning skills were incorporated into the program by including them as part of the instructional strategies. Students saw connections among and interactions of various content areas (i.e., history and philosophy, safety instruction, curriculum, methods, school-to-work transition, and student leadership) by organizing the courses into a concurrent block. Utilizing the strategy of cross-disciplinary techniques allow candidates the opportunity to observe good teaching. At WWU, the guiding principles for development and implementation of the instructional strategies are based on recommendations from the Council on Technology Teacher Education (Henak, 1991), which follow:

> In order to realize the full potential from experimental learning in Technology, teacher education implementers need to:
>
> 1. View students as active self-directed learners and treat them more like colleagues than as receivers of lectures, assignments, and grades.
> 2. Include the processes used in technical systems to apply knowledge, discover new knowledge, solve problems, and learn from mistakes.
> 3. Extend the purpose for technology to go beyond the awareness and understanding levels, and enter into the application and problem solving levels of thinking.
> 4. Create environments where students encounter more authentic problem-centered experiences in simulated or real industrial/environmental settings and apply the heuristic method practiced by professionals in the field.
> 5. Reduce individual and competitive learning environments and increase the use of collabo rative group learning experiences in which heterogeneous teams are created, leadership is distributed, positive interdependence is present, and social skills are acquired within an autonomous group.
> 6. Change the structure and approach of technology teacher education curricula from subject-based and teacher-directed to problem-based and student-directed, because

> teaching activity is not experienced as subjects. Instead, teaching activity consists of a series of problems that need to be solved. (p. 3)

A design activity is presented to the students at the beginning of the block. Students must either design/develop a unit of instruction individually or work in a team to develop an entire course. An instructional systems design approach is used for this purpose. The unit/course content they develop must be stated as learning outcomes. Appropriate instructional strategies, learning activities, and resources must accompany each outcome. Assessment strategies are developed that will allow both students and the instructor to know when the designated content outcomes have been met. An instructional management system is developed that tracks the instructional process, reflects student progress, and incorporates the philosophy of the instructor. Safety instruction, tech prep, and school-to-work outcomes and student leadership skill development must be reflected in the content and methods developed. This curriculum design activity becomes the focus for the development of virtually all the competencies of the five professional courses in the block. This way, students get a holistic view of the process and learn to align the various components of a quality program.

Development and Identification of Instructional Resources

At WWU, a variety of resources have been identified in sufficient quantities so that students will be able to complete most learning activities without reliance upon the instructor's knowledge. Learning resource materials provide students with choices and accommodate variation in learning styles. The acquisition of some resource material has been made the responsibility of the students in the class both independently and in student teams and as a joint effort between students and faculty. However, most of the resources required to meet the competencies are available prior to the beginning of the class. At WWU, these materials include the following types:

- Field trip visitations.
- Guest speakers.
- Professional journals.
- Internet sites.
- Computer-based instructional materials.
- Tutorials (instructor and student developed and commercial).
- Collection of existing curriculum materials.
- Previous student projects and other work.
- Catalogs and examples of commercially developed materials.
- Materials from professional associations, both state and national.
- Experts in the field including teachers, administrators, and others.
- Texts and other reference books.

Development of Assessment Strategies

The purpose and process of assessment is often confused with the process of grading. Grading is for the purpose of assigning a letter grade, usually based on some numerical data gathered through assignments, quizzes, and exams. Frequently this process is used as a source of motivation to influence students to "produce" the appropriate feedback required by these assignments, quizzes, and exams. Seldom does it provide accurate data on what skills and knowledge students may have actually learned as a result of instruction.

The true measurement of competency acquisition is found in the concept of authentic assessment; that is, accurately measuring competency attainment. For example, if a student competency is to develop learning activitites, then students develop activities according to specified quality standards. The assessment is a comparison of the student's work to those standards rather than a quiz on activity development. In teacher preparation, the object of this process is for both the instructor and the student to know when the student is capable of carrying out a specific teaching task. Authentic assessment also incorporates appropriate quality standards for task performance, in this case, the skill expected of a student intern or beginning teacher.

Authentic assessment seldom includes the traditional objective-type tests, although it does not altogether rule them out. At WWU, competency performance is sometimes observed and often involves a product. Both conditions are measured to determine if the performance or the product meets agreed-upon standards. It is not expected that a student achieve the quality standard on the first attempt; therefore, frequent and appropriate feedback is provided from both the instructor and peers as the students work through the activities. Students also have ample opportunity for self-evaluation.

Managing the Instructional Process

The philosophy of the faculty at WWU is that completion of all competencies at the required quality standard is within the capability of every student in the class. To accomplish this, however, takes planning on the part of both the instructor and the students, both individually and collectively. Students are allowed to work on each competency until that standard is met. This requires self-assessment and peer-assessment strategies; final assessment is the responsibility of the instructor.

The question of grading is always on the minds of students at the beginning of the block. They have been well conditioned to think of grades accompanying GPAs. If appropriate standards have been set for each competency and the student meets those standards, then the only grade possible is an "A." The question is, What happens when the student does not meet the standard settled on the first day of class? Several options are discussed including arriving at some lesser grade, either at the discretion of the faculty or in consultation with the student, or assuming the work is still in progress and awarding an "Incomplete."

The entire process requires students to submit work on a continuous basis for feedback. It is important that students understand that they should make a strong effort before initially submitting work, but that the first attempt is not the final evaluation. The process involves making continual progress until the prescribed standard is met.

Some students do better work, do it faster, and do more of it. It is not the point of authentic assessment, however, to distinguish between students' achievement rates, unless competition among students is considered a desired outcome. Care should be taken to not discriminate against individual conditions and style. If the competency is met at the required standard, then allowances can be made for individual style factors. It is possible for biases and personalities to creep into the process at this point.

The management system takes into consideration all of these issues. Its main purpose is as a planning tool to assist students in planning and evaluating their work. It also provides a record for instructors and incorporates opportunities for instructor feedback. At WWU, the instructional management system incorporates the following characteristics:

- Students and instructor establish a plan for completing the competencies, which includes a schedule for the following:
  - Field and guest speaker schedules.
  - Tentative work deadlines.
  - Class discussions.
  - Final assessment deadlines.
- Provisions are made for teaming, collaboration, and cooperative learning.
- A student self-assessment procedure is developed.
- Peer assessment procedures are developed.
- Appropriate feedback is provided.
- Student progress is tracked on a spreadsheet and made available to students.
- Total quality learning principles are utilized including student development of mission and vision statements and a code of conduct.
- Students are given opportunity to make recommendations for quality improvement.
- Students are involved in the process.

The management system also sets the tone for the class. In this process, the instructor acts more as a facilitator or coach rather than a lecturer and controller. Students have more say in the process, with respect and trust being the most common factors.

Evaluation of Program Effectiveness

The final step in the process—one critical for improvement—is the continuous evaluation of program effectiveness. The best source of information for this is the students. They know when they are learning or if they are not learning. The traditional evaluation of teaching procedures found on many university campuses is mostly designed around issues of promotion, tenure, and merit, which may not be appropriate for measuring the effectiveness of a program. Much of the evaluation work will be incorporated into establishing the competencies in the first place. Materials must be updated periodically. It is also important to collaborate with other faculty in the process in order to share and discuss different ideas. Program evaluation activities can include the following:

- Student evaluations of teaching.

- Follow-up/supervision of student interns.
- Follow-up of program graduates.
- Constant review of the literature (including presentations and publications).
- Continual feedback from students.
- Total quality improvement materials/techniques.
- Periodic competency validation surveys.

All of these procedures are used at WWU. Feedback from students, teachers and administrators in the field, and other faculty, and an ongoing review of relevant literature indicate that the process is working. Extensive revisions to the program were made in the summer of 1997 through a summer teaching grant, and further evaluation will take place to measure any improvements gained.

This article reflects only one approach to improving technology teacher education and incorporating an outcome- or competency-based model. During the last two years at WWU, the students have chosen to develop an entire course as a class project for fulfilling the competencies. The feedback from these classes and the resulting work indicate that not only is the process working, but that the results are far superior to those attained when the courses were taught in a more traditional mode. As these students become teachers, the effectiveness of the approach will truly surface. Current evidence suggests, however, that at the very least, these students are far more enthusiastic about teaching and far better prepared for their employment interviews than previous students.

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Pedagogy vs. Andragogy: A False Dichotomy?

Geraldine Holmes and Michele Abington-Cooper

This article is not pointedly aimed at technology education, but it addresses an issue that is becoming increasingly germane to educators working with nontraditional students—a larger segment of the people we teach. **CI**

What is an adult learner? Much of the literature on adult learning indicates that teachers teach adults differently than pre-adults and that most of the contrasts are associated with teachers' perceptions of learner characteristics. An awareness and acceptance of our values and an understanding of our personal philosophies are very important before forming a working definition of what and who an adult learner is to us.

Age is the characteristic mentioned often when describing an adult learner. Most educators assume that it is easy to distinguish an adult learner from a younger learner – just look at the difference in years. But the difference goes beyond age and years. Think about the many possible concepts of an adult such as a dictionary's definition or biological, physiological, legal, social, psychological, spiritual, and moral definitions. These concepts include defining an adult as fully developed and mature, as someone who can reproduce him or herself, as someone who is responsible for his or her own actions, as someone who can legally vote, and as someone who exhibits behavior that indicates a sense of right and wrong.

The various concepts of an adult learner become even more confusing when we try to integrate them with our personal beliefs of what an adult learner should be. It is usually risky to to make generalizations about behavior based solely on age. Also, in reflecting on the many concepts of an adult, there are important individual questions we have to consider. What will we use to build the educational framework for our adult learners? What will we use to guide us in our actions in our treatment of adult learners? Whose concept of an adult learner will we use?

According to Davenport and Davenport (1985), the identification of what is unique about adult learning (in contrast to child or youth learning) has been a long-standing effort in adult education. They reasoned that if this difference could be identified, then the research territory of adult education could be based on these theoretical distinctions.

Before 1950, many educators assumed the same theories of learning and instruction worked for both adults and children. Since formal education in the United States has focused largely on those between ages 6 and 21, most research before the mid-1960s centered on people in these age groups. Many teachers of adults begin to question the validity of pedagogical assumptions in the early 1960s.

Pedagogical and Andragogical Models

The histories of pedagogy and andragogy are both interesting and complex. Pedagogy evolved in the monastic schools of Europe between the 7th and 12th centuries. The term is derived from the Greek words *paid*, meaning "child" and *agogus* meaning "leader of." Thus pedagogy literally means the art and science of teaching children (Knowles, 1973).

Pedagogical assumptions made about learning and learners were based on observations by the monks in teaching simple skills to children. These assumptions were further adopted and reinforced with the spread of elementary schools throughout Europe and North America in the 18th and 19th centuries. When educational psychologists started scientifically studying learning around the turn of the 20th century, they limited their research mostly to the reactions of children and animals to systematic instruction. This reinforced the pedagogical model (Knowles, 1980).

In the early 1920s when adult education began to be organized systematically, the teachers of adults found some problems with the pedagogical model. One was that pedagogy was based on the premise that the purpose of education was the transmittal of knowledge and skills. Adult learners seemed to feel this was insufficient and frequently resisted teaching strategies that pedagogy prescribed, such as lectures, assigned readings, drills, quizzes, note memorizing, and examinations. Dropout rates were high. Teachers also noted that many of the assumptions about the characteristics of learners in the pedagogic model did not fit their adult students (Knowles, 1980).

The term *andragogy* was coined in 1833 by the German teacher Alexander Kapp, who used it to describe the educational theory of Plato (Nottingham Andragogy Group, 1983). A fellow German, John Frederick Herbert, disapproved of the term, and the term subsequently disappeared from use for almost a century. By 1921, the term had reappeared in Europe, and during the 1960s it was used extensively in France, Holland, and Yugoslavia (Davenport, 1987). Andragogy was first introduced to the United States in 1927 by Martha Anderson and Eduard Linderman, but they did not attempt to develop the concept (Davenport & Davenport, 1985). Lindeman did, however, emphasize a commitment to a self-directed, experiential, problem-solving approach to adult education (Davenport, 1987).

Knowles (1980) was exposed to the term *andragogy* from a Yugoslavian adult educator in the mid-1960s. His definition of andragogy was developed as a parallel to pedagogy. Andragogy is based on the Greek word *aner* with the stem *andra* meaning "man, not boy" or adult, and *agogus* meaning "leader of." Knowles defined the term as "the art and science of helping adults learn" in an effort to emphasize the differences between the education of adults and children (Davenport, 1987).

According to Knowles (1980), the goal of adult education should be self-actualization; thus, the learning process should involve the whole emotional, psychological, and intellectual being. The mission of adult educators is to assist adults to develop their full potential, and andragogy is the teaching methodology used to achieve this end. In Knowles' view, the teacher is a facilitator who aids adults to become self-directed learners (Darkenwald & Merriam, 1982).

Although Knowles' definition of andragogy focuses on the teacher's role, his andragogical theory is based on characteristics of the adult learner. His four assumptions are that as individuals mature (a) their self-concept moves from that of a dependent personality toward one of increasing self-directedness, (b) they accumulate a growing reservoir of experience that becomes a rich resource for learning and a broad base upon which they can relate new leanings, (c) their readiness to learn becomes increasingly more oriented to the developmental tasks of their social roles and not the product of biological development and academic pressure, and (d) their time perspective changes from one of future application of knowledge to one of immediate application, giving them a problem-centered rather than subject-centered orientation to learning (Darkenwald & Merriam, 1982; Davenport, 1987; Knowles, 1973, 1980).

According to Darkenwald and Merriam (1982), these assumptions epitomize much that is important about adult learning and development. The first two assumptions (that adults are independent beings and have forged their identities from unique personal experiences) are drawn from humanistic philosophy and psychology. The last two assumptions (dealing with an adult's readiness to learn) help us understand adult learning from a psychosocial development perspective. These assumptions, when combined with principles related to the learning process, can offer the adult educator an understanding of the interrelationship between adulthood and learning.

In order to further distinguish between the pedagogical and andragogical approaches to design and operate adult educational programs, Knowles (1973) compared his andragogical model of human resource development with that used by most traditional educators, which he called a *pedagogical* model.

The pedagogical model is a content model concerned with the transmitting of information and skills. For example, the teacher decides in advance what knowledge or skill needs to be transmitted, arranges this body of content into logical units, selects the most efficient means for transmitting this content (lectures, readings, lab exercises, films, tapes, for example), and then develops a plan for presenting these units in some sequence.

By contrast, the andragogical model is a process concerned with providing procedures and resources for helping learners acquire information and skills. In this model, the teacher (facilitator, change-agent, consultant) prepares a set of procedures for involving the learners in a process that includes (a) establishing a climate conducive to learning, (b) creating a mechanism for mutual planning, (c) diagnosing the needs of learning, (d) formulating program objectives (content) that will satisfy these needs, (e) designing a pattern of learning experiences, (f) conducting these learning experiences with suitable techniques and materials, and (g) evaluating the learning outcomes and re-diagnosing learning needs.

Pedagogy versus Andragogy: The Debate

Although andragogy has become popular both within and outside adult education circles and andragogical approaches are commonly employed in adult education, nursing, social work, business, religion, agriculture, and even law. It has had its opponents as well as its proponents. Much of the controversy stems from a difference in philosophy, classification, and the underlying values attached to the term *adult education* (Davenport & Davenport, 1985).

Houle (1972) preferred to view education as a single fundamental human process and felt that even though there were differences between children and adults, the learning activities of men and women were essentially the same as those of boys and girls. He rejected andragogy as an organizing principle in adult education and perceived it as a technique. He was joined by London (1973) and Elias (1979) in questioning andragogy's theoretical status, general utility, and how it was different from progressive education applied to adults. They preferred to stress the oneness or unity in education. In 1980, Knowles retreated somewhat by stating:

> I am at the point now of seeing that andragogy is simply another model of assumptions about learners to be used alongside the pedagogical model of assumptions, thereby providing two alternative models for testing out the assumption as to their 'fit' with particular situations. Furthermore, the models are probably most useful when seen not as dichotomous but rather as two ends of a spectrum, with a realistic assumption in a given situation falling in between the two ends. (p. 43)

He also indicated that there were occasions when andragogy might be used with children and pedagogy with adults.

McKenzie (1979) defended andragogy on philosophical grounds declaring that "the existential differences between children and adults require a strategic differentiation of education practice" (p. 257).

After a review of the experimental literature comparing andragogical and pedagogical methods, Rachal (1994) concluded: "In general, the bulk of the experimental and quasi-experimental work done to date suggests an approximate equivalence between andragogical approaches and pedagogical ones on both achievement and learner satisfaction. Ultimately, practitioners will continue to employ methods that work for them" (p. 1).

Cross (1981) described Knowles' claim that andragogy could be viewed as a unified theory of adult education as "optimistic." Hartree (1984) found that Knowles' work presented three basic difficulties for adult educators: (a) confusion between whether his theory is one of teaching or one of learning, (b) confusion over the relationship he sees between adult and child learning, and (c) ambiguity as to whether he is dealing with theory or practice. She also questioned the soundness of the basic assumptions underlying the theory or practice of andragogy.

Mohring (1989) took issue with both andragogy and pedagogy. She contended that the terms *andragogy* (implying the education of adults) and *pedagogy* (meaning the education of children) are etymologically inaccurate. Although pedagogy is derived from *paid*, meaning "child," from antiquity it has also stood for education in general—without reference to learners' ages. Andragogy is derived from *aner*, meaning adult male and not adult of either sex, therefore excluding women. In view of efforts to purge English of sexist words, she proposed the use of a new term, *teliagogy*. Based on the Greek *teleios*, meaning "adult," it would include both sexes.

Resolutions or Alternatives?

As an alternative approach to the pedagogy-andragogy issue, Knudson (1980) proposed replacing both with the term *humanagogy* because it is pedagogy and andragogy combined. Unlike the separate terms of pedagogy and andragogy, humanagogy represents the differences as well as the similarities that exist between both adults and children as learning human beings. It approaches human learning as a matter of degree, not kind. Humanagogy might be likened to a "holistic" approach to adult education because it does not throw away what adult educators already know about the way children learn and what they know about the way adults learn; rather, it takes this knowledge and puts it in perspective. Knudson (1980) believed that ignoring the principles of pedagogy from adult education excludes our childhood experiences. He also believed that the concept of humanagogy takes into account the development of the whole human being from birth to death. In presenting the humanagogy approach, Knudson reminded educators that both the pedagogical and andragogical approaches have something to offer. "Like the Chinese symbol of yin and yang, they are at the same time opposites and complements and equally necessary" (p. 8).

In view of the inherent problem associated with the terms *pedagogy* and *andragogy*, Rachal (1983) proposed self-directed and teacher-directed learning. He believed that, in addition to being more self-explanatory, these terms are not restricted to one particular clientele because they eliminate the child-adult issue. The voluntary nature of adult learning activities is one of the cornerstone assumptions of andragogy. Voluntarism, however, is measurable by degree. Employees attending in-service training may be a volunteer only in the most hollow sense of the word. The motivation may be there, but it may be more extrinsic than intrinsic. In relating voluntarism to the self-directed and teacher-directed approaches, the self-directed approach is clearly more appropriate to the highly motivated, preferably intrinsically motivated, learners. Lesser motivated learners may profit from a more teacher-directed approach.

Rachel (1983) noted that these two approaches are not neatly dichotomous and mutually exclusive. The teacher-directed approach would still require the instructor to follow a free exchange of ideas and to allow students to pursue personal interests (through papers, projects, or presentations) as long as they went along with the course objectives. In the self-directed approach, instructors would still set the general requirements for the course and serve as more than merely resource persons. They must also provide leadership and take primary responsibility for evaluation.

Kerka (1994) also addressed the notion of self-directed learning. She dispeled three myths associated with self-directed learning. The first is that adults are naturally self-directed, when, in reality, their capability for self-directed learning may vary widely. The second myth is that self-direction is an all-or-nothing concept. Again, instead of the extremes of the learner versus other direction, it is apparent a continuum exists. Adults have varying degrees of willingness or ability to assume personal responsibility for learning. These may include the degree of choice over goals, objectives, type of participation, content, method, and assessment. The third myth is that self-directed learning means learning in isolation. In truth, the essential dimension of self-directed learning may be psychological control that a learner can exert in any setting—solitary, informal, or traditional.

Davenport (1987) believed that adult education could survive quite nicely without andragogy, but that there is some merit in redefining the term, clarifying it conceptually, and testing it empirically. Because andragogy is such a "catchy" word having public relations value for adult education, Davenport (1987) believed it "simply begs for a second look." In his opinion, redefining andragogy could be as simple as returning to and broadening its original definition. Knowles' (1980) inconsistency in distinguishing pedagogy from andragogy is perceived as part of the problem.

The literal and original definition of pedagogy and andragogy also can allow for both teacher-centered and learner-centered activities. Both the child leader and the adult leader may be at different times directive and non-directive, authoritative and facilitative, etc. (Davenport, 1987).

Expanding these literal and original definitions of pedagogy and andragogy to the "art and science of teaching and facilitating the learning of children" or, in the case of andragogy, adults would also have an advantage. These definitions are consistent with the beliefs and research results of many authors who claim that selection of learning approaches has little to do with age and a lot to do with other variables such as learning style, content, goals of instruction-learning, and even gender (Davenport, 1987).

Davenport's (1987) third step, after acknowledging the public relations value of the word *andragogy* and returning to its original definition, would be to organize knowledge and theory in a systematic fashion. Assumptions, including those of Knowles (1980), have to be placed in the form of a hypothesis and then tested. Only those that survive their trial would become part of the theory of andragogy. Then, andragogy theory would have genuine explanatory and predictive powers.

According to Davenport (1987), this approach would include many similarities between child and adult education and still provide a place for the discovery of differences. In addition to possessing significant public relations value, Davenport believed that "andragogy also has the potential of serving as a unifying framework for adult education if definitional problems can be worked out, and if old and new assumptions are rigorously tested before possible incorporation into a larger theory" (p. 159).

If the andragogy versus pedagogy debate is truly based on different philosophical perspectives of the world, it may never be resolved. Adult educators who adhere to an integrated worldview will reject andragogy and stress unity in education. Those who adhere to a differential worldview will accept andragogy and reject the all-inclusive orientation to education (Davenport & Davenport, 1985). Most important is that the visibility of andragogy has sharpened our awareness and understanding of adult learning.

A major key for educators is to be aware of their personal philosophies for working with adult learners. Zinn (1983) developed the Philosophy of Adult Education Inventory (PAEI) in order to assist adult educators in identifying their personal philosophy and to give them information about their beliefs. The inventory is self-administered, self-scored, and self-interpreted.[1]

This inventory provides a premier—a place for educators to explore their perceptions of learner characteristics. For example, if you find you are inspired by a humanistic philosophy, but your students need someone to clearly direct their learning process, then this may cause problems.

Many theorists believe the andragogy-pedagogy classification is not perfect, but they cannot agree on a viable alternative either. Polson (1993) asked the question: "Is the 'adult learner' a recognizable, single entity for whom there is one best way to teach, or for whom there is one best way to learn? No. There is no agreement in the literature as to what constitutes an adult learner." Perhaps, given the very nature of those engaged in educational research, the solution is not to find an answer, but to continue to ask acute questions!

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[1] Permission to reproduce and use the PAEI© may be obtained by contacting the author at Regis College, West 50th and Lowell Blvd., Denver, CO 80221-1099. Phone (303) 458-4088.

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Cost-Effective CNC Part Program Verification Development for Laboratory Instruction

Ted C. Chang and Joseph C. Chen

Cost is a major basis for action in both manufacturing organizations as well as in higher education. The increasing expense of acquiring an industrial technology degree is a serious problem that cannot be ignored. In industrial technology education, the per-capita cost is particularly high because of the nature of the instruction, which often requires relatively expensive laboratory components. Consideration of any possible means for keeping expenses down to the lowest figure consistent with excellence and efficiency in laboratory learning is a definite advantage. In a computer numerical control (CNC) part-programming course, this cost-reduction goal can be attained by checking the part program thoroughly before loading it into the machine control unit (MCU). This article presents a cost-saving procedure for completing a CNC lab project using a CNC part program verification system developed in-house.

Typically, a CNC lab project includes the following activities (Figure 1):

1. Create the CNC part program on a personal computer (PC) or on the machine.
2. Debug the program (i.e., find and remove errors).
3. Check the program visually for obvious mistakes.
4. Try out the program on a computer or a plotter, where the tool path can be simulated.
5. Download the CNC program into the MCU.
6. Perform a dry run, machine lock, Z-axis feed neglect, or single block (Lynch, 1993).
7. Cut the workpiece.
8. Repeat step 2 if any errors are found in steps 3 to 7.

Debugging is a major part of CNC part programming, and it is very time consuming. A part programmer could spend several frustrating hours to debug a large and complicated program. Vendor programming stations and third-party CAD/CAM (computer-aided design and manufacturing) software can be used to generate part programs. Even though these commercial part programs are more

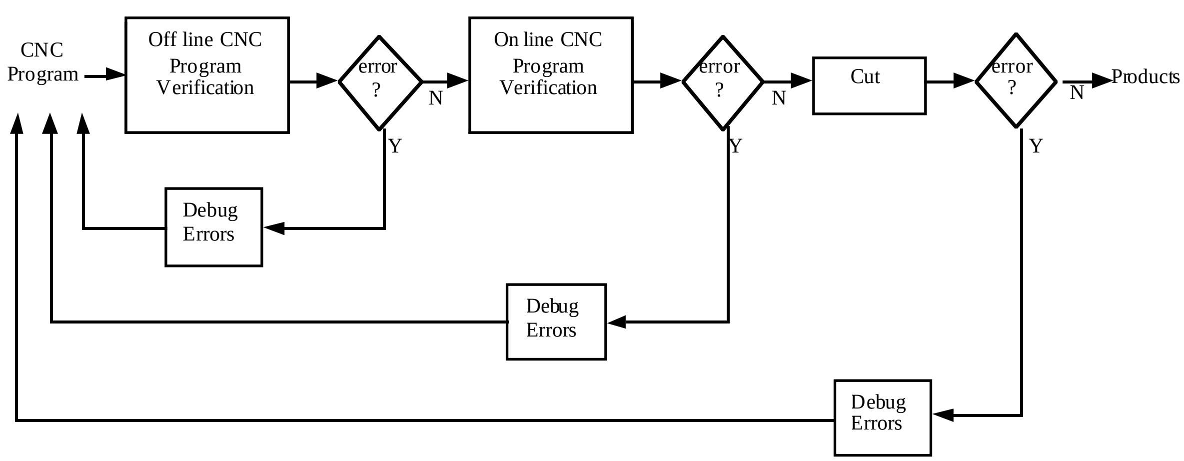

Figure 1. Overview of CNC programming learning activities.

efficient and less error-prone than manual debugging, such software tools are often too expensive or otherwise unsuitable for specific CNC labs (Prasad, 1992). Therefore, developing a part program verification system in-house that is more effective and economical than commercial software is of obvious value.

Advantages of Developing and Using an In-House Part Program Verification System

A CNC program verification system is a computer software package used to check the correctness of a part program offline before it is executed online. The advantages of using the part program verification system are summarized as follows:

1. Suppression of leading/trailing spaces/zeroes, empty lines, and so on. If a student writes an NC block that includes "N20 G01 0X0. 110" as a command, machine-errors will be caused by the mistakes in the underlined section. These mistakes include a leading 0 and an extra space. In-house part programs will detect these errors to correct mistakes so that the block reads: "N20 G01 X0.110". Between 20 and 100 of these blocks are present in typical student programs; errors such as those indicated above are often difficult for students to observe and correct manually. By sensing and correcting these errors automatically, the in-house part program saves students frustration as they learn new skills, thus increasing their learning efficiency.
2. More efficient use of in-class time: Class time will be more productive because debugging time is drastically reduced.
3. Ease and safety of using the part program (Lynch, 1994): The CNC part program is checked by the verification system before it is downloaded into the controller. Using an effective tool, instead of trial and error, on a CNC project allows the movements of the cutter and the workpiece to run smoothly and according to plan. Thus, students will feel comfortable, safe, and confident when working with their programs. Students' attitudes toward learning CNC programming will be more positive and productive.
4. Reduction of wasted time and materials: When programs are verified offline, i.e. (not on the CNC machine), the machine can be used for real cuts. Students will enjoy success the first time with only one piece of material needed for each of their projects. Most important, students, instructors, and the machine all benefit from the amount of time and material saved.
5. Reduction of tool and machine costs: Pre-checked part programs will prevent unexpected damage to tools and machines, thus reducing costs and lag time due to repair.

Overview of Numerical Control

Over the last few decades, the utilization of computers in manufacturing has been one of the most significant developments in improving the productivity and quality of manufacturing systems (Singh, 1996). Numerical control (NC) was one of the earliest computer applications used to control individual manufacturing functions on the shop floor level. Most CNC machines in use today are metal-cutting machine tools. As shown in Figure 2, CNC machines basically consist of a machine tool and MCU, also known as the machine controller.

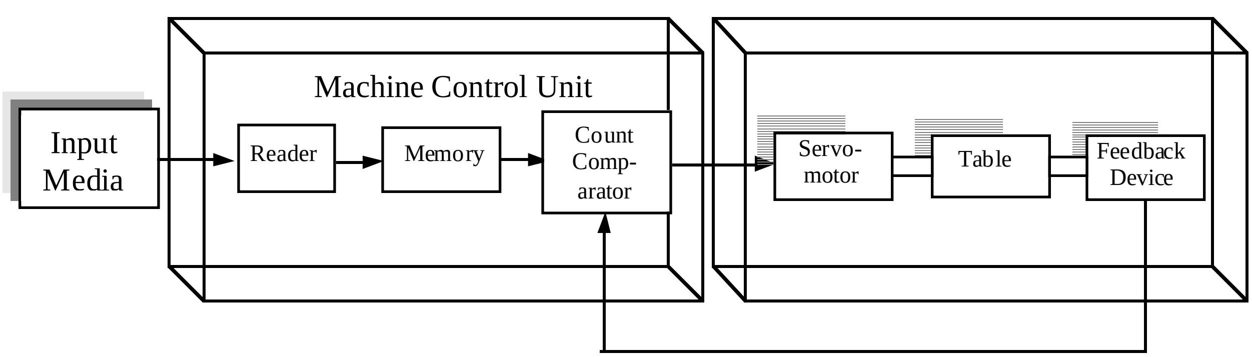

Figure 2. Block diagram of the CNC machine.

CNC machines must be programmed for each different part they produce. The collection of instructions used to produce a part on CNC machines is called a CNC part program. The instructions are entered into the MCU in a serial manner. Then, the MCU interprets these instructions and generates signals to each of the drive units of the machine to accomplish the required action. There are four basic types of input media: keyboard (manual data input), punched tape, magnetic tape, and direct numerical control/distributive numerical control (Seames, 1990).

Structure of the CNC Part Program

Figure 3 shows the bottom-up hierarchy of CNC part program elements. A CNC part program is essentially a string of characters. A character usually requires 8 bits of memory to represent its control value. A bit is the basic unit of memory. The control value of a bit is either 1 (high, on) or 0 (low, off). Characters used in CNC part programs can be classified into three categories:

1. Capitals: A - Z
2. Digits: 0 - 9
3. Special Symbols: (, /, %, etc.)

Characters are often grouped into words (or commands). Each command directs a specific element of control data (e.g., a machine speed or a tool number). The basic categories of commands are listed as follows:

1. Sequence or block number (N, H, or P code): Identifies a block.
2. Preparatory function (G): Prepares the MCU to perform specific operations.
3. Miscellaneous functions (M): Specify certain miscellaneous or auxiliary functions available on a particular machine tool.
4. Dimension words (X, Y, Z, etc.): Specify the coordinate position of the cutting tool.
5. Feed words (F): Specify the feed rate of the cutting tool.
6. Speed words (S): Specify the spindle speed.
7. Tool number (T): Identifies and selects a tool from an automatic tool changer.

Commands that remain active until canceled by another code are called modal commands; rapid traverse and speed commands are examples of modal commands. A nonmodal command is one that is active only in the line in which it is issued, such as the dwell command.

Words can be grouped into blocks (statements). The way in which individual commands are arranged within the block is referred to as the block format (Singh, 1996). The three primary block formats used in the industry are fixed sequential, tab sequential, and word address.

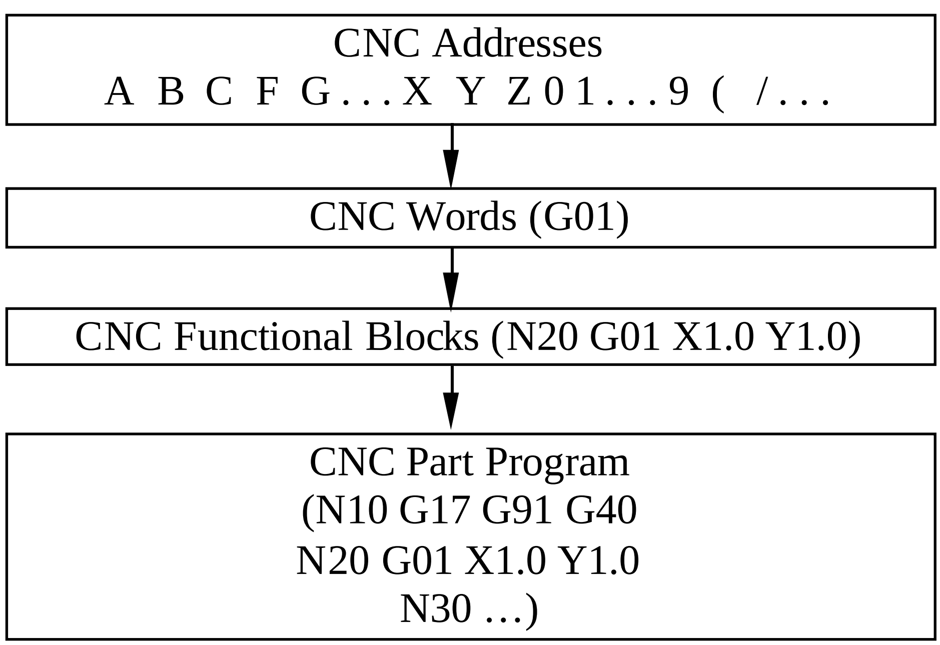

Figure 3. Structure of the CNC part program.

In the fixed sequential format, each block consists of exactly the same number of words entered in a specified order, each word consisting of a fixed number of digits. The tab sequential format is essentially the same as the fixed sequential format, but they differ in that a TAB character precedes each word within a block, except for the first word. In the tab sequential format, the TAB character for a specific word does not need to be followed by a number if the number is not required in that block.

The word address format is used on virtually all modern CNC machines. It is considerably easier to use than the other two formats. A word consists of a letter code followed by associated numeric data. Normally, only the negative sign has to be entered if required. Different words have different numbers of digits. A programmer writing a program should know the format specification for the machine that will run the program. Some machines allow suppression of leading zeros, while others can suppress trailing zeros. Certain machines require that decimal points be entered explicitly as part of the command data. The number of spaces and the number of empty lines allowed in a program also vary from machine to machine.

Blocks are grouped in CNC part programs. The following are the basic methods used to create part programs (Thyer, 1991):

1. Manual programming.
2. Computer-aided programming (CAP).
3. CAD/CAM-based programming.

For some parts, it is easier and faster to manually create a part program directly in word addressed format. On the other hand, the use of computers with part programming languages such as Automatically Programmed Tools (APT) considerably reduces the labor involved in creating part programs for complicated parts.

Advances in computer capabilities combined with the fall in the cost of computing have led to the development of more sophisticated computer-aided design (CAD) systems with far better part definition capabilities than APT. Well-developed part definition capabilities of CAD systems have been combined with the machining capabilities of part programming systems in a logical progression. These combined systems are called CAD/CAM systems. Most CAD/CAM systems can directly generate a cutter location file, which can be post processed for use on specific machines.

Table 1. An Example of a Student's CNC Program with Errors.

N10 **01001** (* should be O1001)
N**@0** G90 G17 **670** S2000 F500. (*N20 and G70)
N30 M6 **T112** (* tool #12 – T12)
N40 G0 E28 X0. Y0. Z0.5 M3
N50 X0.5 Y0.5
N60 **G0** Z-0.1875 (*G01)
N70 X2.5
N80 Y2.5
N90 X0.5
N100 Y0.5
N110 G0 Z0.5
N120 **E0** X0. Y0. **ZO. (*G28 and Z0.0)**
N130 M02

Developing a CNC Part Program

Table 1 shows a CNC part program written by a student for the Fadal VMC40 CNC machine. The first line of the part program is the BEGIN block, which serves as a program identifier, and the last line is the END block, which will stop all movements of the machine table, spindle, etc. The rest of the part program performs other functions and machine operations. The string, starting with a left parenthesis at the end of each block, is a comment. This program has many errors, which are indicated in bold fonts. The controller of the VMC 40 machine is capable of pointing out some of the errors online; the offline utility of the machine is capable of the same. Some severe errors, however, cannot be detected, e.g., 670 and F500 on line N20, and G0 on line N60. Undetected, these errors could result in unexpected damage and injury. Some CNC machines, especially older machines, do not have these capabilities and the utilities. Therefore, a CNC part program verification system is being developed for CNC machines, particularly for older machines.

Developing and Using a CNC Part Program Verification System

The CNC program has a particular structure that the controller can understand, but it must follow a specific syntax. Writing CNC programs is an error-prone process;

debugging a program of any sizable length is usually very tedious. Often, a computer-assisted part programming language can be used to perform tedious and/or complex calculations necessary to prepare the program. However, even with this help, some important commands of a program could still be missing, or the program could be incomplete or incorrect with regard to factors like spindle speed, tool size, fixture offset, depth of cut, feed rate, and tool path. These mistakes could cause damage to the tools and the machine, and injuries to the operator and other people as well. For these reasons, the tool path should be checked for errors before the part program is run on the machine.

As shown in Figure 4, the CNC part program verification system consists of four major components: the character recognition system, word recognition system, fuzzy-nets system (FNS), and the tool path viewer. The tool path viewer is the last to be developed, after the other components have been implemented. The input to the verification system is a CNC part program and the output is a correct CNC part program.

The function of the character recognition system is to separate characters of CNC part programs into tokens such as keywords, word identifiers, special symbols, and constants. If an error is detected, the system will prompt the user to modify the code and recheck it. Otherwise, the tokens are passed to the word recognition system.

The word recognition system is a module that groups the tokens together into block structures. If an error is detected, the system prompts the user to modify the token and recheck it; otherwise, the token is stored into memory for later use.

Figure 5 shows the flow chart of the character recognition system and the word recognition system. The input is "N@0 G90 G17 670". In the character recognition system, the invalid character "@" is detected. It should be a "2." The words "N20", "G90", "G17", and "670" are passed to the word recognition system. The invalid word "670" is detected and the user is prompted to enter the correct word.

The fuzzy-nets system is an area of artificial intelligence (AI). It is formed by combining artificial neural networks (ANN) and fuzzy logic (Pal & Srimani, 1996). In classical logic, a proposition is either true or false. If a proposition is true, it has a truth-value of true; otherwise, its truth-value is false. Fuzzy logic implies a nonclassical logic with more than two truth-values. Artificial neural network models are composed of many nonlinear computational elements (nodes) operating in parallel and arranged in patterns similar to biological neural networks (Lippmann, 1987). The fuzzy-nets system combines the advantages of the learning capabilities of artificial neural networks and the reasoning capabilities of fuzzy logic.

Figure 6 shows the structure of the FNS. The inputs to the FNS are machining parameters such as speed, feed rate, and depth of cut, and the output is the required cutting power. If the cutting power exceeds tool strength or machine capability, the FNS will prompt the user to modify the values of the parameters. For example, as shown in Table 1, the combination of the words "S2000" and "F500" on line N20 and the word "T12" on line N30 will exceed the strength of the tool. The FNS fuzzifies

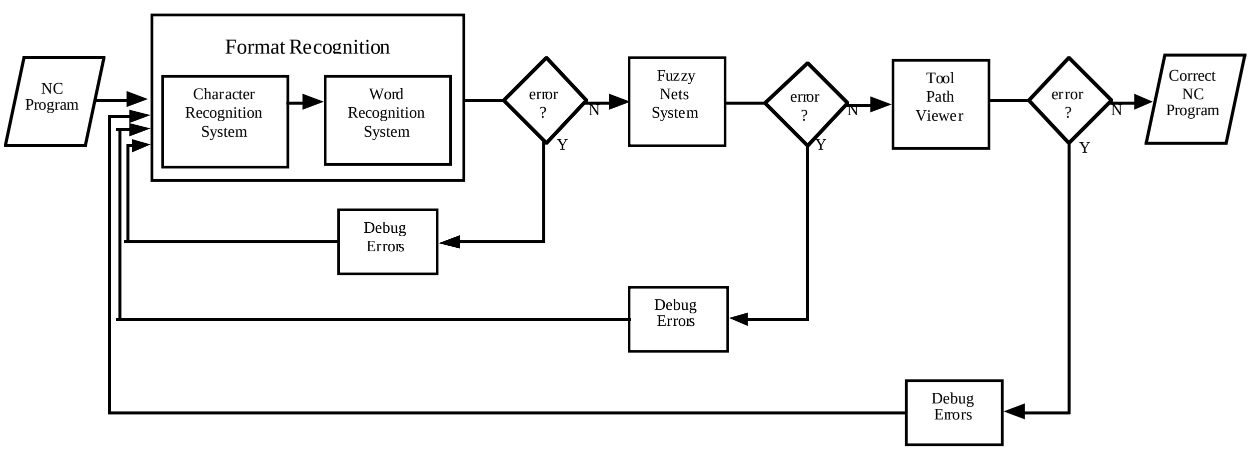

Figure 4. Architecture of the CNC part program verification system.

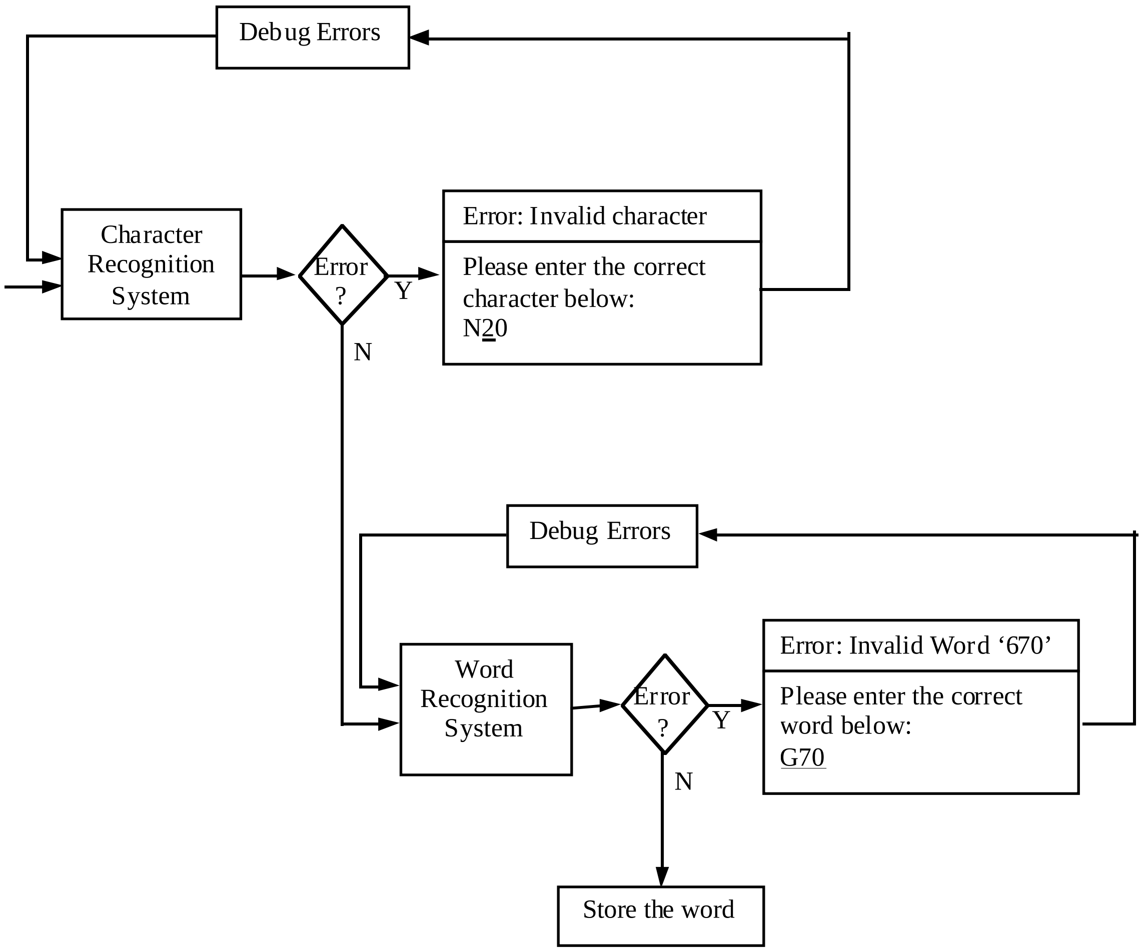

Figure 5. Flow chart of the characters recognition system.

the inputs, retrieves fuzzy rules from the rule (knowledge) base, defuzzifies the data, and informs the user of the errors**.**

In this study, the performance of the fuzzy-nets system was examined for an end milling operation using a Fadal VMC40 CNC machine. The experimental setup is shown in Figure 7. The cutting force signal was measured by a three-component dynamometer mounted on the table of the CNC milling machine with the workpiece mounted on it. The output voltage signal of the charge amplifier was collected by a personal computer with an Omega DAS-1401 high performance analog and digital (A/D) board installed to sample the data online. The data sets were collected to train and test the system.

Implementation

The task of developing a CNC part program verification system is now much easier than before due to advances in (a) integrated development of environments for languages such as C++; (b) object-oriented programming (OOP); (c) powerful graphics software, techniques, and matching hardware; and (d) a variety of CASE (computer-aided software engineering) tools and powerful debuggers to further reduce cycle time (Prasad, 1992).

The CNC part program verification system will be a graphical user interface (GUI) or Windows-based application written in C++ using object-oriented technology. Programming in C++ is very popular because of the wide acceptance of its parent language, C, and its data abstraction and object-oriented features (Dewhurst & Stark, 1989). Object-oriented programming involves three key concepts (Microsoft, 1993):

1. Abstraction, which makes writing large programs simpler.

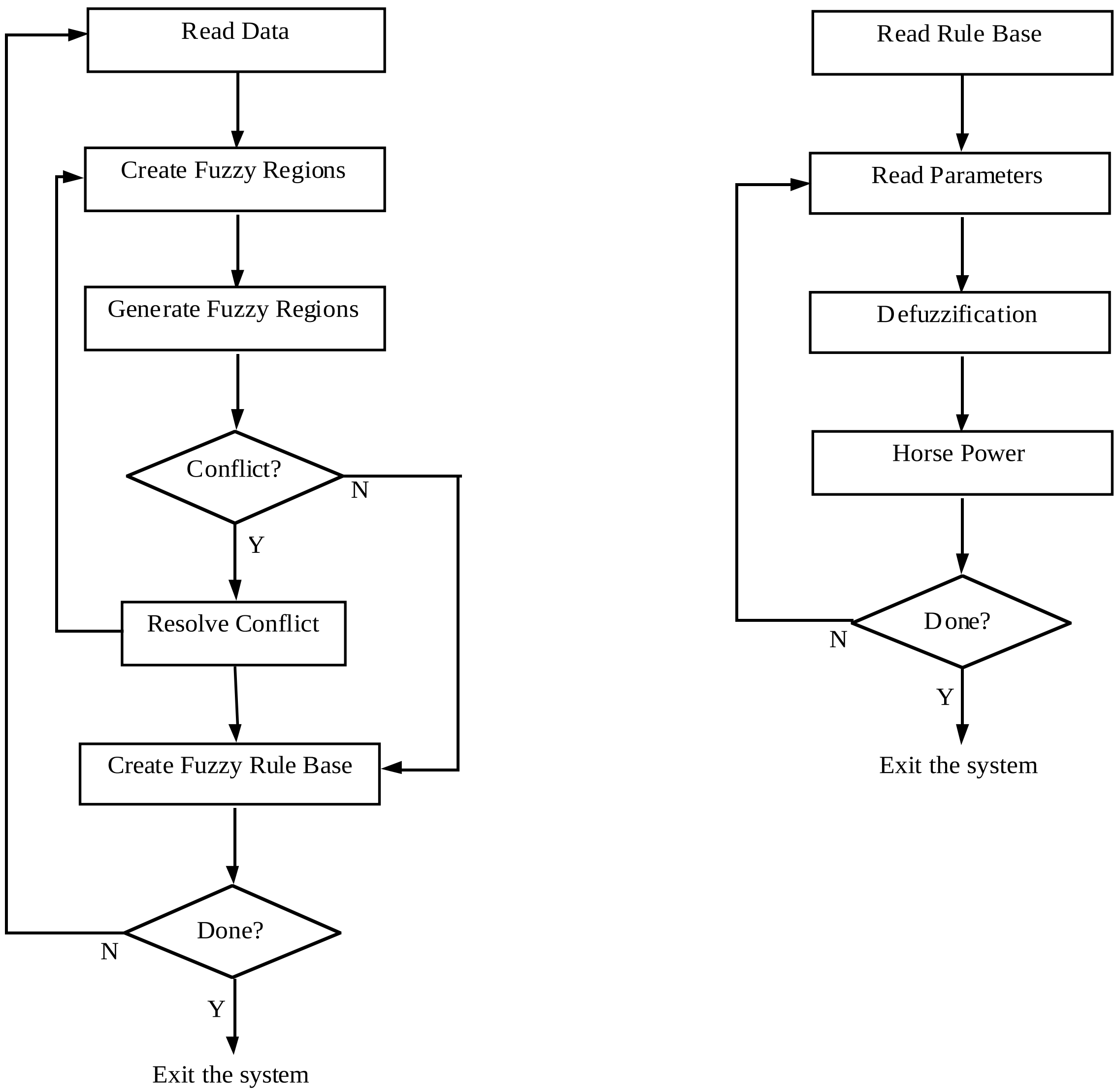

Figure 6. Structure of the fuzzy-nets system: fuzzification and defuzzification.

2. Encapsulation, which makes changing and maintaining a program easier.
3. Class hierarchies, a powerful classification tool that makes programs more user-friendly.

A GUI employs windows, icons, menus, toolbars, boxes, buttons, and other images. It is much easier to use than command-driven and menu-driven user interfaces. Minasi (1994) noted that a good GUI application should be predictable, attractive, easy to read, customizable, and forgiving. In addition, good GUI applications help to make people more productive.

Summary

Financial control is important in industrial technology education. One way to reduce the cost of technical instruction is to prevent damage to equipment and tools. Using general-purpose CAP and CAD/CAM systems for CNC part programming is not satisfactory because they are generally expensive and unsuitable for most applications in the CNC lab. Instead, CAM tools designed for specific processes incorporating special utilities are preferred for writing efficient CNC code.

In this study, a CNC program verification system was developed to check the CNC part program before its execution on a CNC machine. The verification system includes four components: the character recognition system, the word recognition system, the fuzzy-nets system, and the tool path viewer. The system is a GUI application and is written in C++ using object-oriented technology. It is user-friendly and easy to learn in a graphics environment. Developing and using CNC verification systems will enable the participant to be more productive in learning CNC programming; consequently, the verified part program will be more efficient, safer, and easier to manage. The authors believe that the development of this in-house CNC part program verification allows benefits to the CNC laboratory education; proving more effective in both learning and instruction.

Joseph C. Chen and Tao C. Chang are both associate professors in the Department of Industrial Education and Technology at Iowa State University. Both are EPT members as well, in the Alpha Xi chapter.

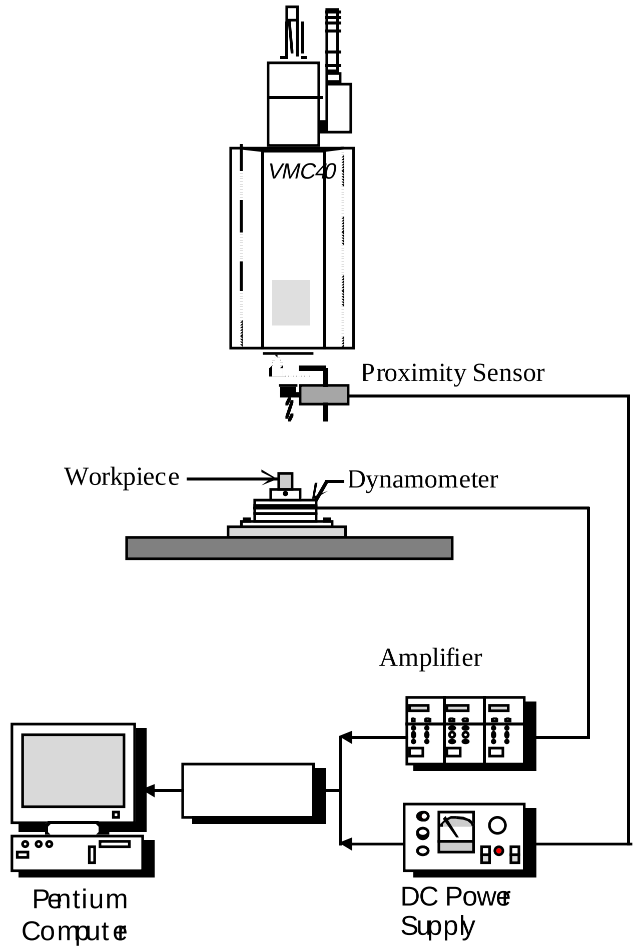

Figure 7. The experimental setup.

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On-Line and In-Print: A Possible Future for Epsilon Pi Tau Publications

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This note is prompted by our belief that the following possibilities will allow us to capitalize on technology to provide improved services to members and subscribers.

We contemplate that beginning with *The Journal of Technology Studies* volume XXVII for 2001, all materials will be published electronically and be available to readers and subscribers on one or more websites.

In doing this, authors will be better served as they will be able to submit articles electronically and have their materials reviewed and edited using that vehicle.

Although we will begin with the equivalent of two issues for the volume year as has been the case over the preceding years, we will monitor the new system with a view toward increasing the number of issues per volume year.

As a transitional device: at the end of the volume year, when the two (or more) numbers of the 2001 volume are complete and on line, we will supply to all active members and subscribers a printed volume containing all the materials published for that year. The efficacy of this printed volume will be evaluated and its continuance will depend upon member and subscriber reaction.

Our vision for other Epsilon Pi Tau publications that serve members is closely connected to the contemplated change in *The Journal of Technology Studies*. The current *Quote-Unquote* periodic newsletter is the Epsilon Pi Tau publication of record. The type of information that is currently provided will continue. But we are contemplating expanding the newsletter into a magazine format and hope to provide it in two or more issues each calendar year. We hope to include articles and items of interest to our diverse membership, information that will not only be informative, but will enhance the professional development of our student and practitioner members.

We close by repeating our invitation for your comments.