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ABSTRACT

A report and a bibliography are provided from a project designed to provide a greater understanding of sophisticated technologies and to provide direction for vocational education curriculum revision in Illinois. The report begins with an introduction. Section 2 provides a conceptual and operational understanding of sophisticated technologies by identifying, defining, and developing a classification scheme. Section 3 considers technology as a means of restoring the United States to its former competitive status and addresses the impact of technology on the work force, both on future occupations and on skill requirements. Section 4 reviews and analyzes recent work force competency literature and summarizes interviews conducted. Conclusions are made regarding the competencies of the work force of the future. Section 5 discusses education to prepare the future labor force, including secondary and postsecondary vocational programs, core-plus-specialty curriculum design, tech prep 2+2, and advanced technology centers. Section 6 makes recommendations for the future direction of vocational education in Illinois. Thirty-four references are appended. The Sophisticated Technology Bibliography contains 155 references related to sophisticated technologies, the future work force, and vocational education. Each entry consists of the following: author or sponsoring institution, date of publication, title, place of publication, publisher, and key words. (YLB)

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Sophisticated Technology, the Workforce, and Vocational Education

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Adult, Vocational and Technical Education

Sophisticated Technology, the Workforce, and Vocational Education

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SECTION 1

INTRODUCTION

The Problem

This nation's quality of life is dependent upon the ability of our workforce to adapt to the changing workplace. As technology has advanced, so has the complexity of technical knowledge and equipment. As a result of these changes, it is becoming increasingly difficult for workers to know all there is to know about the technical systems with which they work. Therefore, future workers must have the skills which enable them to acquire the additional knowledge and skills that are needed to work with new and emerging technologies.

Much of the content of vocational education programs is related to technology. Many current vocational programs, however, appear to lack a strong philosophy regarding the nature of technology upon which the curriculum is designed. There are so many varying philosophies and perspectives regarding the term "technology" that there appears to be no primary definition for this commonly used word.

In addition to the lack of consensus on terminology and philosophy, current trends in vocational and technical education suggest that the traditional vocational curriculum may not equip students with the skills needed to work with sophisticated technologies. The knowledge base of technology has changed in recent years. The change in knowledge which results from the development of new technologies requires changes in the content to be taught in vocational education. The technical skills needed by future workers are also changing because of the advances in technology. The most effective and efficient method of preparing future workers may no longer include vocational education's traditional emphasis on specific technical job skills. Because of the rapid and complex changes in technological knowledge and skill, the specific technical job skills taught in many vocational programs are obsolete when vocational graduates enter the workforce. Hence, specific technical job skills are no longer a sufficient condition for employment. The emerging trend is toward an increased emphasis on transferable, basic skills. By helping students gain generic skills along with basic technical skills, graduates of vocational programs will have the "transferable" skills that are needed to keep up with the rapid changes in the workplace.

All of the changes in technology are forcing vocational educators to be responsive to the needs of the changing workplace by revising their current curriculum content, using different instruction methods, transforming facilities, and updating their own technical knowledge and skills. However, it has not been easy for vocational education to respond to the necessary changes. The problem for many vocational educators and policy makers may lie in a lack of understanding of:

1. the characteristics of sophisticated technologies,
2. the knowledge, skills, and attitudes required to work with sophisticated technologies, and
3. the effective strategies for integrating the necessary knowledge, skills, and attitudes into current vocational education curricula.

The Project

A major goal of vocational education is to provide students with the knowledge, skills, and attitudes needed for entry-level employment and job advancement. Before designing effective vocational education programs that meet this goal, a deeper understanding of the knowledge, skills, and attitudes needed to work with sophisticated technologies is required. This project has been developed to provide a greater understanding of sophisticated technologies and to provide direction for vocational education curriculum revision in the State of Illinois. During the 1989 fiscal year, the goals of this project were to:

1. provide a conceptual and operational understanding of sophisticated technologies by identifying, defining, and developing a classification scheme for those technologies,
2. identify the competencies (knowledge, thinking processes, and technical skills) needed to work with sophisticated technologies,
3. determine the role of vocational education in teaching the knowledge, skills, and attitudes needed to work with sophisticated technologies, and
4. develop recommendations for planning the integration of the necessary knowledge, skills, and attitudes into existing vocational education curricula in Illinois.

SECTION 2

SOPHISTICATED TECHNOLOGY

The Nature of Technology

Technology is a very common word that is used in many different ways. The term "technology" is used in newspapers and magazines; it is the focus of news reports and public television specials, and it is viewed both as the solution to and the cause of many of the worlds' problems. Each of the following phrases serve to show the diverse uses of the term "technology."

- "Our technology is being exported . . ."
- "Developing nations lack the technology to . . ."
- "The technology is TOP SECRET."
- "We have the technology to . . ."
- "Technology is increasing at a phenomenal rate."
- "Technology is out of control."

Because the term technology is used by so many people in so many ways, it is difficult to reach consensus about the meaning of the term. For example, Ballesteri (1988), in a review of the literature, identified over 50 different definitions of technology.

Is there a clear understanding of this commonly used word? What is technology? Is it the computer on the desk? Is it the process that is used to make the computer? Is it an area of formal study like the sciences and humanities? Is it applied science? The answers to these questions can provide the conceptual foundation needed to understand the impact of technology on the workforce and vocational education.

Views of Technology

While there are many different views of technology, Frey

(1987) has identified four common categories; technology as an object, technology as a process, technology as knowledge, and technology as volition.

Technology as an object. Technology is often viewed as an object. A large group of people view tools, machines, and consumer products as technology. A common example of an object that is viewed as technology is the computer. People often say, "the computer *is* technology" or "I am uncomfortable with that technology." Evidence of this view can be found in the many school districts across the nation that have established "technology committees." Because most of these technology committees were created to identify the types of computers and software to purchase, it would be more appropriate to call them "computer committees."

Vocational instructors also view technology as devices and equipment. Based on this view, instruction would focus on the gadgets and "magic" of technology. Many traditional vocational programs seem to have developed their curriculum around this view of technology. The primary emphasis of these programs is on the types of devices and equipment that are available and on what they can do.

Technology as a process. The second category of technology views technology as a process. Rather than viewing technology as an artifact (i.e., tools, devices, equipment), technology is viewed as the process used to produce those artifacts. A common approach to defining technology at this level is to stress the importance of the *application* of knowledge for the making of objects. Emphasis is placed on the physical and technical processes and procedures that are used to produce objects. Many vocational programs have traditionally stressed this view of technology. In addition to learning about tools and equipment, students are taught the processes needed to use and operate the tools and equipment in order to design and produce objects.

Technology as knowledge. The third category of technology views technology as knowledge. According to this view, technology is more than an object or a process. Technology is the knowledge that underlies the development of processes that are used to make the artifacts of technology. Emphasis is placed on the technical and scientific concepts, theories, and principles that underlie the objects and processes of technology. Therefore, technology can be viewed as a discipline because it has its own body of knowledge and patterns of thinking.

Technology as volition (culture). The fourth category of technology views technology as a complex socio-cultural system. According to this view, technology is much more than machines, techniques, and precise knowledge. Pacey (1986), in a very thorough discussion of this view, stresses the importance of the human and social aspects of technology. Pacey describes his conception of technology as one that contains organizational, technical, and cultural aspects. Most people identify technology with its technical aspect because it has to do with machines, techniques, knowledge, and activity directed at making things work. Beyond the technical aspect of technology, however, there is a set of beliefs and values that are influenced by the predominant culture. It is these cultural aspects that drive technological development and determine the degree of control a particular society will place upon various technologies.

A Conceptual Definition of Technology

Indeed, technology is a term that does have many different meanings and uses. But is there a philosophically based definition that captures the true nature of the term? The following definition is offered as a conceptual definition of technology:

> Technology is a noumenon that occurs through the synergistic interaction of knowledge, thinking skills, and physical processes and results in the extension of human capabilities.

According to this conceptual definition of technology, technology is not tangible; it is not directly observable by the senses. Therefore, technology is viewed as a *noumenon*; something that is based purely on intellectual intuition as opposed to being observable by the senses. You cannot touch it, see it, or smell it. The physical manifestations that we often view as technology are *evidence* that the noumenon of technology exists. For example, while a computer is often viewed as technology, it is not synonymous with technology. The computer is an artifact of technology; it is the result of some type of technological activity. The

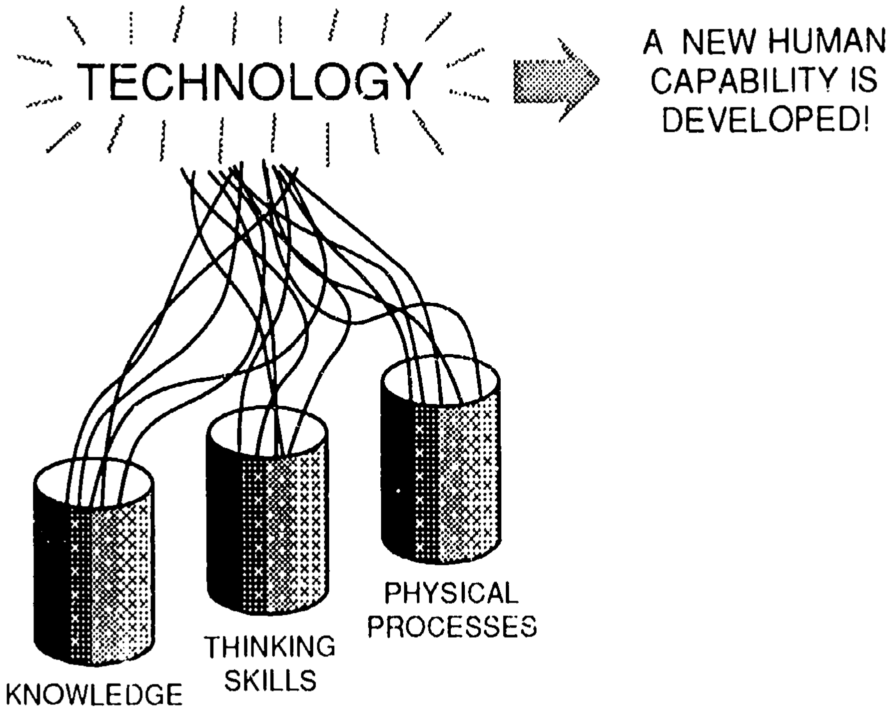

Figure 1. The Noumenon of Technology.

processes used to produce technical artifacts certainly incorporate technology but they are also not technology. Processes are only the means used to carry out technological activity. The above four common views of technology (i.e., as an object, as a process, as knowledge, as culture) are evidence that technology exists. They prove that something exists which enables humans to satisfy their wants and needs by facilitating the acquisition and application of knowledge and skills to create and produce tools, equipment, and processes.

Technological Activity

Technology occurs through the interaction of knowledge, thinking skills, and physical processes. But as a noumenon, technology cannot extend human capabilities unless it is used in some way. Technological activity can be viewed as the application of the noumenon of technology in order to extend human capabilities.

Technological activity is a complex socio-technical system that is composed of six distinct components; wants and needs, knowledge, thinking skills, physical processes, extension of human capabilities, and impacts (Johnson, 1988). Through the interaction of the six components in the *Interactive Model of Technological Activity*, a synergism occurs which results in the whole becoming greater than the sum of the parts. Because of this synergistic effect between the six components in the model, a change in one component results in a change in the rest of the system.

As shown in Figure 2, all technological activity is driven by human wants and needs. To satisfy the wants and needs, physical and mental activity begins. Mental activity involves the use of knowledge through various cognitive processes such as planning, problem solving, and decision making. Physical activity involves carrying out the plans that are developed through the thinking processes. This activity involves the use of various resources and techniques. The result of this interaction may or may not result in the satisfaction of the wants and needs that began the technological activity. If the wants and needs are not satisfied, further technological activity may be needed. The technological activity model does not end with the satisfaction of human wants and needs through the extension of human capabilities. There are both positive and negative impacts that result from all technological activity. These impacts affect the values and philosophies from which the wants and needs are determined.

Technological activity is a cyclical process that appears to be never ending (see Figure 3). As human values and philosophies change because of the impacts of technology, new needs, wants, and intentions develop which leads to further technological activity.

Much of the content of vocational education involves the study of technological activity. Therefore, any curriculum that is designed to teach about technology must include *all* aspects of the *Interactive Model of Technological Activity*. Vocational education curricula must include the study of the human values and philosophies that drive technological activity, the study of the interaction between the knowledge, thinking skills, and physical processes that occurs through an attempt to satisfy human wants and needs, and the study of the impacts which result from technological activity.

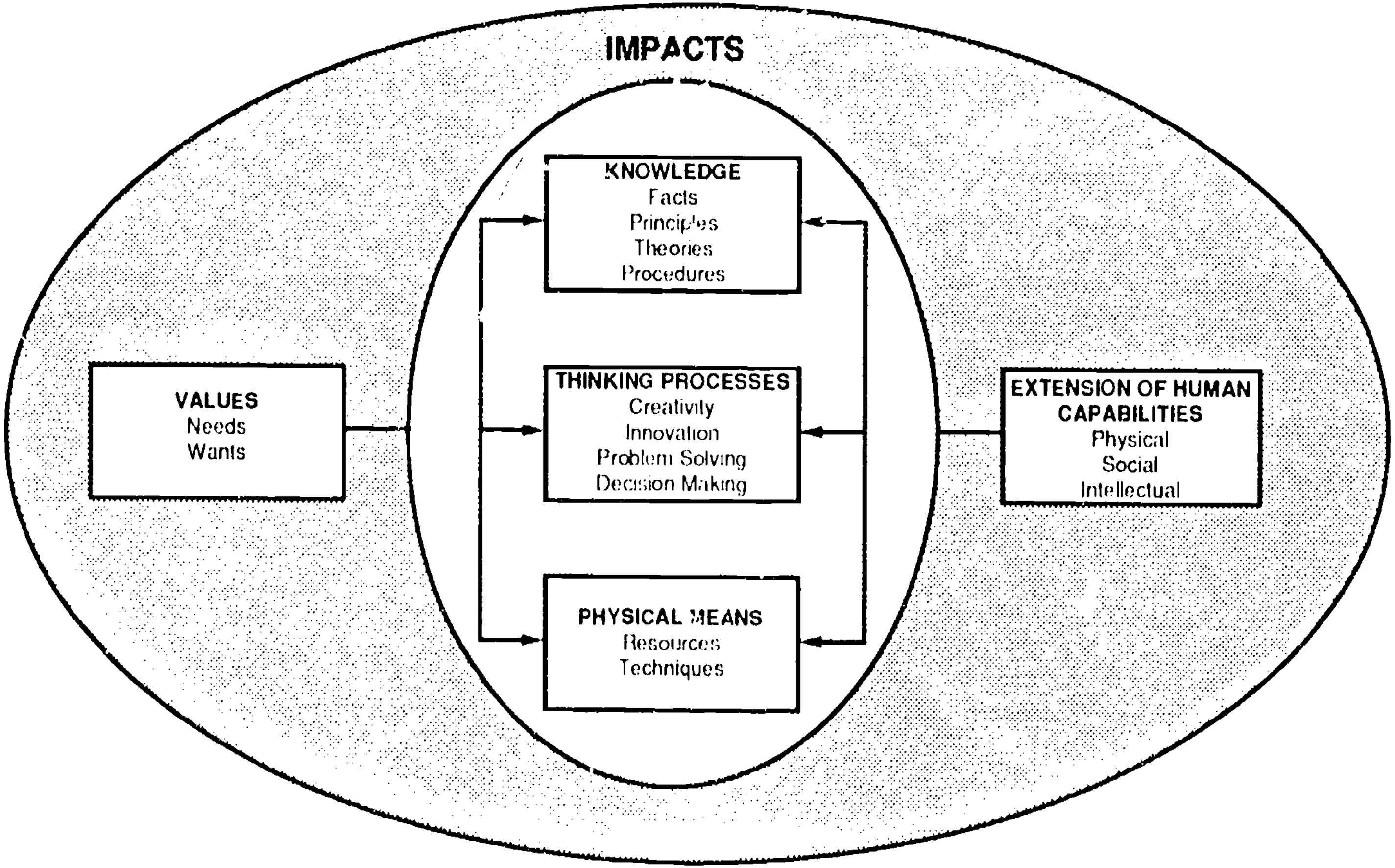

Figure 2. Interactive Model of Technological Activity.
Source: Johnson, (1988)

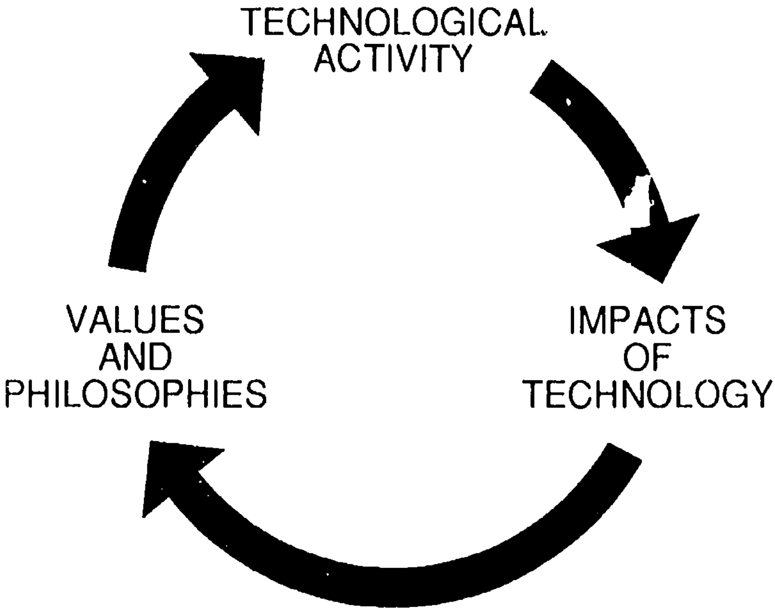

Figure 3. The Cyclical Nature of Technological Activity.

A Developmental Theory of Technology

The development of new technologies can be viewed as an event. A new technology is created when someone sees for the first time that they are able to extend their capabilities by using their knowledge and skills in a unique way. From that time on, the new technology can be utilized, it can be refined, and it can result in the development of newer technologies.

The creation of a new technology can be explained through a phenomenon called a "slot theory." A new technology is created at the specific point in time when all of the prerequisite conditions (slots) in the three areas of knowledge, thinking skills, and physical processes have been met. Prior to that point, at least one element was absent from the prerequisite conditions (slots) of knowing, thinking, or doing. Once all of the slots are filled, a new technology exists. This technology can then be used to extend human capabilities, to refine the new technology, and to facilitate the emergence of newer technologies.

Evidence of this "slot theory" can be found in every example of the development of technology. For example, in the superconductivity area, the slots that have enabled technologists to simulate superconductivity with supercooled materials have already been filled. Therefore, the technology exists (i.e., all the necessary slots are filled) to produce superconductivity with materials that are at very cold temperatures. However, from a practical standpoint, this new technology is not very useful because it is currently impractical to utilize the technology because of the difficulty of keeping the materials cold. Slot theory says that there is an additional set of slots that must be filled in order to refine the current superconductivity technology. As soon as someone combines the right materials or discovers the right combination (i.e., as soon as the additional set of slots are filled), a practical and viable superconductivity technology will have been created.

The creation of a new technology adds to the knowledge base and often results in the development of new physical processes which facilitate the development of newer technologies. Therefore, technological development is a cyclical process. New technologies provide information and techniques that fill the prerequisite slots for other technologies. As technologies are developed, the knowledge base of technical information and processes continues to grow, thereby facilitating the development of new technologies and new knowledge.

An Operational Definition of Technology

While a conceptual definition of technology may provide for interesting philosophical discussions, it does not directly contribute to the lay person's understanding of technology. It is doubtful that such a conceptualization of technology will be useful in practical situations. Given the many uses and meanings for the term technology, it is also doubtful that one definition will become generally accepted as *the* definition. It is anticipated that popular opinion will rule out. Therefore, it is accepted that technology will continue to be viewed by the general population in many different ways.

Rather than attempt to provide a single operational definition of technology, it may be best to identify a set of generally accepted common characteristics. The following list provides an initial set of characterizations of technology:

- Technology is applied human knowledge. Because technology uses information from all domains, it is more than applied science.
- Technology is application based. It is more than knowledge because it involves a combination of knowledge, thinking skills, and physical processes (i.e., knowing, thinking, doing).
- Technology extends human capabilities. It increases the survivability of the human race by enabling humans to adapt to and change the physical world.
- Technology exists in social domains as well as physical domains. Technology can be both "hard" (e.g., tools, equipment, etc.) and "soft" (e.g., management systems, software, etc.).

A Conception of Sophisticated Technologies

Sophisticated technologies are the most advanced technologies that currently exist. They incorporate the latest knowledge and processes and constitute the latest refinements in existing technologies. As sophisticated technologies become widely used in a relatively routine manner, they become "mature technologies." As newer, more advanced technologies are developed, the mature technologies become outdated and are replaced by the sophisticated technologies.

Since the arrival of the early settlers, the United States has gone through three distinct technological ages (see Figure 4). Initially, the United States was an agricultural society with the vast majority of the population living and working on farms. With the advent of the industrial revolution, the United States was transformed into an industrial nation. The development of large scale electronic circuit integration, which resulted in the development of the microprocessor, ushered in the information age. Figure 4 illustrates that the level of sophistication rises with each subsequent age. In addition, it should be noted that the number of people employed in agricultural pursuits declined drastically during the industrial age, and a similar decline is projected in industrial jobs as the information age progresses.

A similar increase in the level of sophistication can be seen

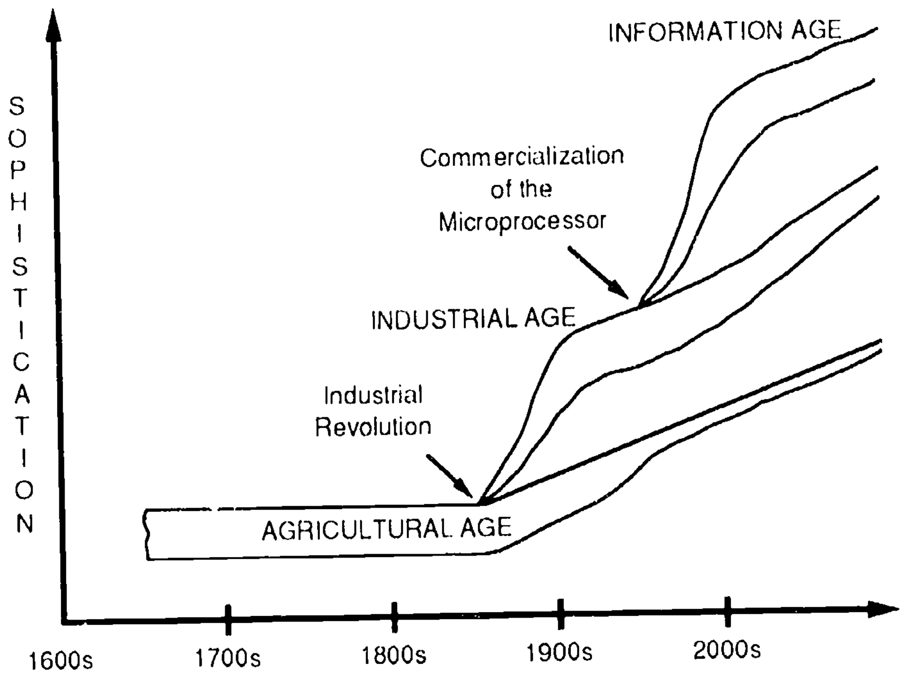

Figure 4. Increasing Sophistication Through Time.

when considering individual technologies. Figure 5 exemplifies the increase in the level of sophistication as newer technologies were applied to the turning of metal. With the introduction of a more sophisticated technology, the previous technology became a "lower" technology and is referred to as a mature technology. Consequently, a technology can only be considered sophisticated when it is juxtaposed to the prior technology. In most cases today, it is the application of electronics and the replacement of human power with machine power which makes a technology sophisticated.

The comparison between mature technologies and sophisticated technologies can be repeated for every form of technology. In every case, mature technologies are being replaced with more sophisticated technologies.

A Taxonomy of Technology

Vocational education has placed arbitrary boundaries around the study of technology. Business education, industrial educa-

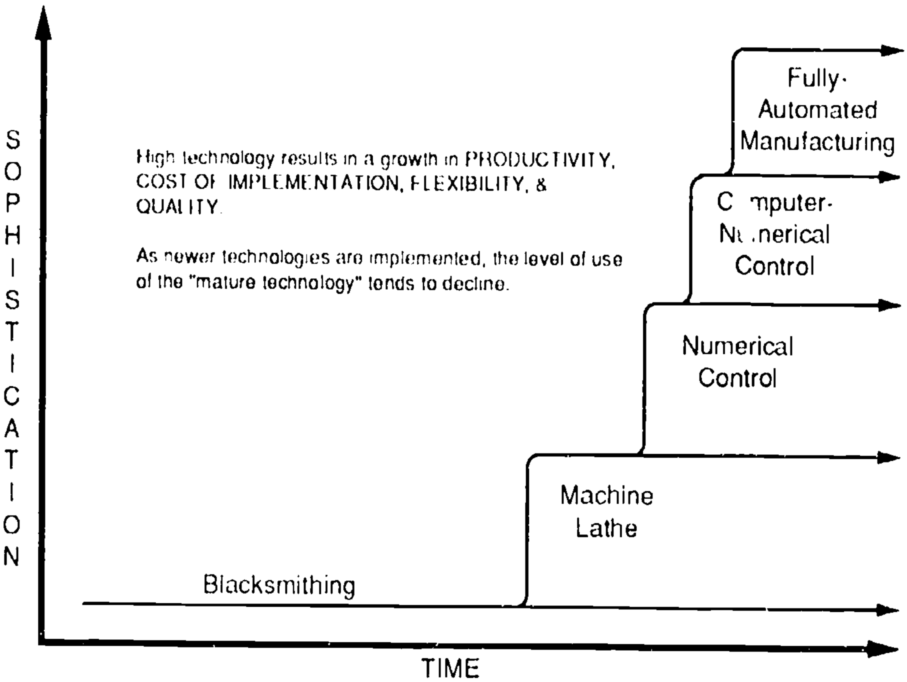

Figure 5. Increasing Sophistication of Metal Fabrication.

tion, home economics education, health occupations, and agricultural education are all examples of the artificial boundaries that serve to limit the teaching of technology. Within each of these curriculum organizers, technology is taught as a separate and distinct phenomenon. The relationships that exist between the technologies across these boundaries are lost within the current curriculum.

However, technology knows no boundaries. Technology is much larger than business, industry, home economics, health occupations, and agriculture. Technology includes all of these areas and much more.

Rather than attempt to constrain the teaching of technology by using these artificial boundaries, it seems logical to conceptualize the teaching of technology around broader characteristics of technology such as the physical technologies, the biological technologies, the informational technologies, and the organizational technologies. A brief description of each category is provided below:

- **The physical technologies.** The physical technologies are those technologies that enhance the physical capabilities of humans. Included in this category are technologies that are used to build structures, produce goods, and transport people and goods.

- **The biological technologies.** The biological technologies are those technologies that enhance the biological capabilities of humans. Included in this category are technologies that are used to maintain life by producing better foods and drugs and improving techniques for diagnosis, treatment, rehabilitation, and prevention of the biological problems that humans encounter.
- **The informational technologies.** The informational technologies are those technologies that enhance human abilities to manage information. Included in this category are technologies that enhance communications, knowledge acquisition, and data management.
- **The organizational technologies.** The organizational technologies are those technologies that enhance the ability of humans to manage people, processes, and other technologies. Included in this category are technologies in the areas of economics, education, manufacturing, and politics.

SECTION 3
TECHNOLOGY AND THE WORKFORCE

The Competitiveness Problem

While the United States was once the premier leader in industrial strength and influence, countries previously unable to compete with the United States in both technological and economic arenas have made drastic changes in the way they develop and produce goods. Through modernization of their factories and by using innovative organizational systems, these so called non-industrial countries have begun to compete with the industrial giants on their own turf. New competition from countries such as Japan, Korea, and Brazil is having a dramatic impact on the economical, political, and educational systems within the United States. Examples of the results from this new competition include rising trade deficits, an increasing budget deficit, slow productivity growth, stagnant real wages, and a declining share of world markets (Young, 1988). All of these trends constitute a threat to the American standard of living. Unless changes are made to increase the competitive ability of the United States on economic and technological grounds, the quality of life in this country is certain to fall.

Although the increased ability of other countries to compete with the United States is certainly a major factor in reducing the competitive advantage of this country, other internal factors have also been identified. The *President's Commission on Industrial Competitiveness* (1985) identified the following primary internal causes of the decline in the competitiveness of this country:

- A failure to develop human resources as well as other nations.
- Inadequate incentives for savings and investment.
- Trade policies that do not address the new realities of international commerce.
- Shortcomings in our commercialization of technology.

In response to the competitiveness problem, this country must strive to develop a high skilled, adaptable workforce that develops and uses technology. This effort would result in a renewed competitive advantage through improved technologies and innovative, creative, and highly educated workers; something which may be the United States' biggest strength. Young (1988) describes the technological strength of the U. S. as (a) having the highest level of scientific and engineering knowledge in the world, (b) producing the highest proportion of research and development scientists and engineers in the world, (c) having the most major technical breakthroughs since World War II, and (d) having ready access to capital and equity for entrepreneurs.

This approach is also not without its drawbacks. New technologies are likely to replace many workers which could result in higher unemployment. Advances in technology could also lead to a deskilling of the workforce which may result in a wider gap between the workers who develop new technologies and those who use them.

To return the United States to its former competitive status, improvements must occur in productivity and in the ability to commercialize the technologies that are developed. Improvements in these areas will help bring about a higher standard of living through the development of a high skilled and adaptable workforce that develops and uses technology.

Improve Productivity

The first area where the United States must improve in order to become more competitive is in its level of productivity. It has been said that productivity is the main determinant of trends in living standards (Hatsopoulos, Krugman, & Summers, 1988). Therefore, if Americans are to continue enjoying their high standard of living, they will have to find ways to continually increase their own productivity. Recent evidence shows that competitors have been able to increase their productivity at a much faster rate than the U. S. For example, the U. S. was ranked below eleven of its competitors in productivity growth from 1973 through 1979 and from 1981 through 1985 (Berger, 1987; Klein, 1988). Without an increase in productivity it is doubtful that U. S. companies will be able to successfully compete for much longer. While the statistics point out weaknesses, all is not lost. After the dismal years of the 1970s and early 1980s, U. S. companies have shown productivity improvements in recent years. In 1985, the U. S. had the second highest growth in productivity among the twelve leading industrial countries with a 5.1% increase and in 1986 had the fastest productivity growth at 3.7% (Klein, 1988).

While the recent improvements are encouraging, efforts must be made to ensure that these improvements in productivity continue. There are three primary ways to improve productivity: (a) through the development of new technologies, (b) through increased capital expenditures, and (C) through education and training.

Improve productivity through the development of new technologies. Eighty percent of the U. S. productivity growth is directly or indirectly attributed to technological innovation (Young, 1988). A strong research and development effort is needed to ensure that new innovations are forthcoming. Without research and development expenditures, it is doubtful that significant innovations can be developed. While the U. S. has been successful in developing new technologies in the past, it not likely to continue to be successful if current trends continue. Business and government expenditures for civilian research and development are a smaller proportion of the economy in the U. S. than in other developed countries (Berger, 1987). A continued commitment and support for research and development must be made if the U. S. is to maintain its leadership in the development of technological innovations.

Improve productivity through increased capital expenditures. While the development of technology is a key to productivity growth, the technology is worthless unless it is actually used. A primary reason the U. S. has lost its competitive advantage in the steel and automobile industries is because those industries have been slow to realize that modern facilities, new equipment, and innovative organizational strategies are needed to keep up with the rest of the world. In recent years, U. S. competitors have been tooling up with modern facilities that incorporate the latest technologies and strategies such as robotics, computer-integrated manufacturing, just-in-time manufacturing, and the Japanese philosophy of Kaizen. At the same time, U. S. steel and automotive industries were trying to produce goods in antiquated facilities with pre-World War II technologies and traditional authoritative management strategies. The result of the unwillingness of these U. S. industries to expend the necessary capital to build new facilities and to acquire new technologies has been a decreased share of world markets, increased layoffs, and reduced profit margins. As an example of the discrepancy between U. S. capital expenditures and those of Japan, the Japanese spend 50% - 100% more per employee on capital than the U. S. To compound the problem, U. S. capital costs 50% - 75% more than Japanese capital (Hatsopoulos, Krugman, & Summers, 1988). On a positive note, the recent surge in productivity in the U. S. can be partially attributed to the willingness of companies to begin investing in new capital.

Improve productivity through education and training. As stated by the *President's Commission on Industrial Competitiveness* (1985) this country has failed to develop its human resources as well as other nations. This problem becomes evident when comparing our educational system with those of other countries. Only 70% of the students in American schools successfully complete high school while 98% of the Japanese students complete high school (Jonas, 1987). The recent plethora of national reports that focus on educational reform further support the need for strengthening America's educational systems (Carnegie Forum, 1986; National Commission on Secondary Vocational Education, 1984; Parnell, 1985).

Even if the U. S. is able to continue developing new technologies and makes the capital expenditures necessary to utilize those developments, great improvements in productivity will be unlikely unless workers have the levels of education and skill needed to handle the advanced technologies (Berger, 1987). In response to this need, educational programs at the secondary and post-secondary levels need to identify the knowledge and skills that will be needed by the future workforce to successfully work with and maintain the sophisticated technologies and develop appropriate delivery systems for the teaching of the new content.

Improve our Ability to Commercialize Technology

In addition to acquiring the best and most up-to-date equipment, this country must capitalize on its ability to develop technology by ensuring that the time between the development of a new technology and its implementation into production is as short as possible. One reason for the lost advantage in the steel, automotive, machine tool, semiconductor, and television industries is the inability of American companies to take these new innovations and commercialize them. While American scientists and engineers may have been responsible for the development of technology in each of these areas, American companies have been slow to integrate them into production. To highlight this problem, it has been determined that it takes U. S. corporations 60 months to produce a car from the initial design stage to the actual production. In contrast, the Japanese are able to design and produce a new car in only 40 months. In the pharmaceutical industry, the U. S. averages five years to get a new pharmaceutical to market while the United Kingdom takes only two and one-half years. Even though the U. S. may have been the initial developer of a new product or technology, it should be clear from these two examples that one cannot be competitive if the competition is able to get their product to market much faster.

The Impact of Technology on the Workforce

There are several views regarding sophisticated technologies and their effect on the workforce (Naylor, 1985; Rumberger, 1984). One view is that sophisticated technologies will be the primary source of new jobs in the future. People read and hear about new jobs being created in the areas of robotics, computers, lasers, and optics. A common belief is that jobs in these areas are completely new and will result in job opportunities for a great many workers. The second view is that sophisticated technologies will vastly upgrade the skill requirements of future jobs. Advances in technology are believed to make jobs much more complex and therefore, will require higher level skills in the future. A third view is that sophisticated technologies will result in the displacement of massive numbers of workers. The development of robotics and automated processes is viewed as a means to eliminate the human worker from the labor force.

It is true that technology is having a definite effect on the nature and characteristics of the workforce. New occupations are being created while traditional occupations are being changed or eliminated. The workers that fill these changing occupations must update their knowledge and skills to remain employable.

A wider variety of skills are now needed by the workforce. The diversity of occupations has increased to the point where workers must do things that were once performed by many different individuals. Future workers still need to have specific technical skills. However, employers are beginning to want their new employees to have better basic skills. Basic skills enhance workers' abilities to learn new information and techniques and will make the future workforce more adaptable as advances in technology further changes the workplace.

It is evident that technology is having a significant impact on the workforce. However, the true nature of that impact is unclear. Are the above views accurate or are they only myths? The following discussion describes some of the impacts of technology on the workforce and presents the uncertainties that exist regarding the changes that will occur in the future.

The Impact of Technology on Future Occupations

The impact of technology on future occupations is unclear. Will the advances in technology result in more sophisticated technology related jobs or will there be an increase in the number of low technology related jobs? The answer to this question is critical to the economic and social well being of this country. To identify the actual impact of technology on future occupations, it is necessary to examine the various views that currently exist.

View 1: Sophisticated technology jobs are growing at a rapid rate. One view regarding job growth in sophisticated technology areas says that sophisticated technology-related jobs are growing at a significant rate. Based on Bureau of Labor statistics, the fastest growing occupations are in sophisticated technology areas. As shown in Table 1, eight of the ten fastest growing occupations may be classified as "high technology" occupations (Kutscher, 1987). These fast growing occupations include technicians, engineers, operators, and repairers. As a result of this information, it would appear that sophisticated technologies will be the primary source of new jobs in the future. In fact, numerous post-secondary schools are using this information to develop new technician level programs in robotics, CAD, CAM, lasers, and computers.

	Percent Change	Change in Total Employment	Percent of Total Job Growth
Computer Service Techs.	97	53,000	0.21
Legal Assistants	94	43,000	0.17
Comp. Systems Analysts	85	217,000	0.85
Computer Programmers	77	205,000	0.80
Computer Operators	76	160,000	0.63
Office Machine Repairers	72	40,000	0.16
Physical Therapy Asst.	68	26,000	0.09
Electrical Engineers	65	209,000	0.82
Civil Eng. Technicians	64	23,000	0.09
Peripheral Elect. Operators	64	31,000	0.12

Table 1. Fastest Growing Occupations (in percentage terms).
Source: Kutcher, (1987)

However, describing job growth in percentage terms does not paint a true picture of the impact of technology on the growth of occupations in the future. A closer examination of Table 1 shows that while the fastest growing occupations are growing at a high rate, they will result in relatively few jobs. For example, the fastest growing occupation in percentage terms is computer service technicians. While this occupation is growing at a fantastic 97% rate, it accounts for less than 1/4th of 1 percent of the total projected job growth. In fact, the ten fastest growing occupations in percentage terms account for less than 4% of the total job growth.

Based on their low percentage of the total job growth, post-secondary schools must be careful when planning to develop new programs for these "fast growing" sophisticated technology occupations. It is possible that many of these new jobs will be filled without the need for numerous sophisticated technology programs. In fact, current data suggests that there are more graduates of sophisticated technology programs than positions available (Grubb, 1984; Naylor, 1985). Continued growth in enrollments will compound that problem.

View 2: Low tech jobs are growing at a rapid rate. A second view regarding the impact of technology on job growth suggests that advances in technology will result in an increase in low technology-related jobs. This view is in direct contrast to the first view. Based on Bureau of Labor statistics, the fastest growing occupations are not in sophisticated technology areas. As shown in Table 2, the majority of the ten fastest growing occupations (in absolute terms) are not in sophisticated technology areas (Kutscher, 1987). For example, the fastest growing occupation in absolute terms is building custodians. While that occupation will certainly change as technology advances, it is not considered a "high tech" occupation. Sophisticated technology occupations are those that require an in depth knowledge of the theories and principles of science, engineering, and mathematics that underlie technology. This definition includes engineers, scientists, mathematical specialists, engineering and science technicians, and computer specialists (Rumberger & Levin, 1985). Note that while the occupations listed in Table 2 are not growing at a high percentage rate, they do account for a great number of jobs. In fact, these ten fast growing occupations will account for almost 25% of the total job growth in the future.

It is true that sophisticated technology occupations are growing at a rapid rate although the impact of that growth is less significant because of the small number of actual jobs that are created. One reason for the inability of sophisticated technology occupations to create a large number of jobs is because of the potential of technology to reduce the need for workers. Automated systems are being incorporated into factories that are able to reorganize traditional production processes. The change from individual machines to complete systems has enabled employers to reduce the number of workers while increasing productivity.

	Percent Change	Change in Total Employment	Percent of Total Job Growth
Building Custodians	27.5	779,000	3.0
Cashiers	47.5	744,000	2.9
Secretaries	29.5	719,000	2.8
General Office Clerks	29.6	696,000	2.7
Sales Clerks	23.5	685,000	2.7
Registered Nurses	48.9	642,000	2.5
Waiter & Waitresses	33.8	562,000	2.2
Teachers	37.4	511,000	2.0
Truchdrivers	26.5	425,000	1.7
Nursing Aides & Orderlies	34.5	423,000	1.7

Table 2. Fastest Growing Occupations (in absolute terms).
Source: Kutcher, (1987)

For example, the integration of robotic welders into the auto industry replaces two to three human welders and achieves productivity gains that range from 5:1 to as high as 20:1.

Based on the above discussion, it should be clear that technology does impact on the total growth of occupations. Sophisticated technology occupations are growing at a high rate yet they are a small fraction of the total job growth. While low technology occupations are not growing at as fast a rate, they contribute to a greater percentage of total job growth. Because it is possible to interpret job growth in different ways, vocational educators must be careful when attempting to identify the need for new programs in sophisticated technology areas. On the one hand, if new programs are developed based on the rate of projected job growth, it is likely that a surplus of qualified workers will be produced which will reduce the employment opportunities for future graduates. On the other hand, if decisions regarding the development of new programs are based on projections of job growth in absolute terms, it is likely that new programs for sophisticated technology oriented occupations will not be developed. This could lead to the lack of qualified workers in important technological areas which could force the business and industry community to become more involved in the initial preparation of future workers.

It is clear that caution must be used when determining whether or not to develop vocational programs for sophisticated technology oriented occupations. Clearly, vocational programs that prepare students to work in these "high tech" areas are needed although not in abundant numbers.

The Impact of Technology on Skill Requirements

Technology will also have an impact on the skill requirements needed for *all* jobs at *all* levels (Rumberger, 1984). As occupational skill requirements change as a result of technology, the education and training needed by future and existing workers must also change. However, are the skill requirements increasing or decreasing as a result of the advances in technology? The answer to this question will have a great impact on the content and delivery of vocational education programs.

The literature identifies three different views regarding the impact of technology on skill requirements. Each of these views will be examined as they relate to vocational education curriculum and instruction.

View 1: Sophisticated technology creates a wider gap between high skill and low skill jobs. The first view suggests that advances in technology will create a wider gap between the high skill level jobs and the low skill level jobs (Nettle, 1986; Rumberger, 1984) which may result in a bimodal distribution of the workforce (Grubb, 1984). Figure 6 graphically shows the potential distribution of occupations based on skill levels if this view is true.

This view is built on the premise that technology creates a need for highly trained and educated workers to design, develop, and maintain the new technologies. These individuals will require some type of college degree which will increase the need for workers with M.A.'s and Ph.D.'s in technical areas. On the other end of the skill continuum are a great number of low skilled, low paid workers who have little need for training. This bimodal distribution is thought to be made up of 80% semi skilled or unskilled workers and only 20% highly qualified and skilled workers (Nettle, 1986).

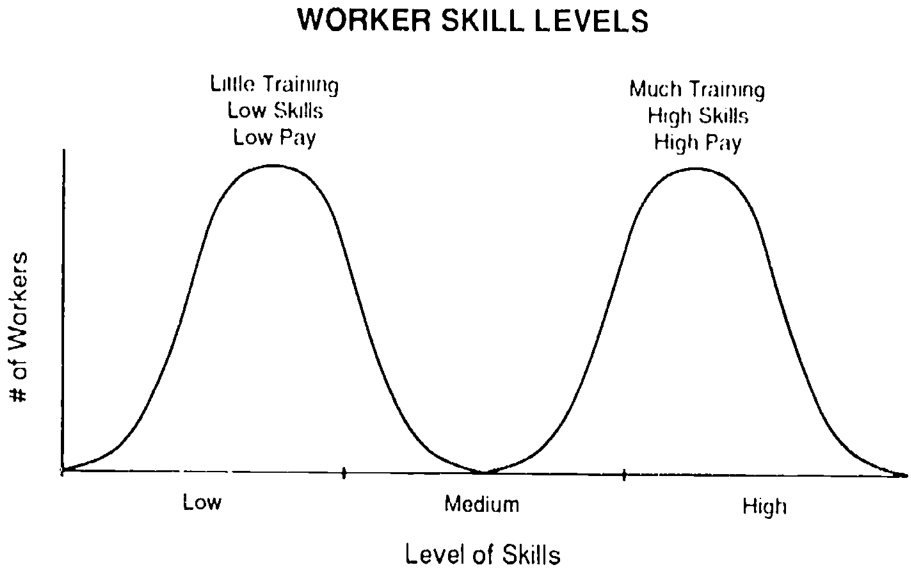

Figure 6. Distribution of Worker Skill Levels.

View 2: Sophisticated technology creates jobs at both middle and high skill levels. The second view suggests that advances in technology creates jobs at both the high and middle skill levels (Grubb, 1984). Data collected for high technology and conventional manufacturing sectors in Texas clearly show that the occupational distribution of sophisticated technology manufacturing is *not* bimodal. Figure 7 graphically shows the occupational distribution between high technology and conventional manufacturing industries based on 1980 Census data. As suggested in the first view, the need for high skill levels increases as sophisticated technology is incorporated. However, in contrast to the first view, Figure 7 also shows that the need for middle level skills increases as technology is incorporated.

While the above data is from one state in one primary industry, the data does corroborate with Bureau of Labor Statistics national data (Grubb, 1984). Sophisticated technology sectors do hire more technicians and computer specialists. In addition, the projected growth in middle to high skill level

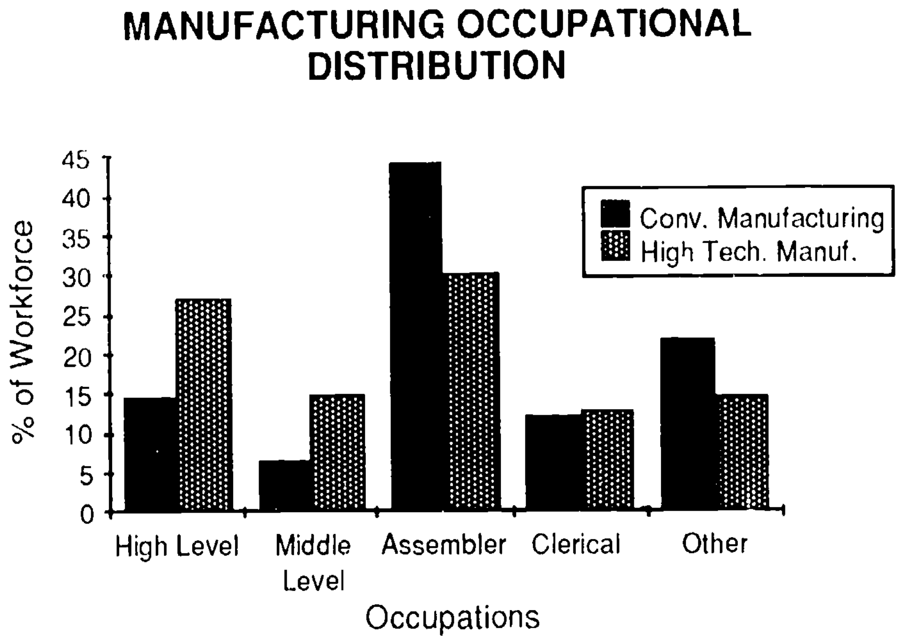

Figure 7. Manufacturing Occupational Distribution.
Source: Grubb, (1984)

technician jobs are higher in most high tech industries than in conventional industries. This is especially true in the health and information technology fields where more technicians are being used to perform very specific tasks, thus freeing the professional to monitor technicians and to perform other tasks.

As low skill level assemblers are replaced by middle skill level technicians, the amount of training needed to obtain the higher skill level positions will increase. Figure 8 shows the difference in the amount of education needed by the workforce in conventional and high technology manufacturing industries. An increased demand for education at the post-secondary level can be projected as technology in integrated into the private sector. If technology increases the need for people with middle level skills and decreases the need for people with low level skills, vocational education should focus on the retraining that will be needed to raise the skills of the assemblers so they can fill the middle level skill occupations that will become available as technology is incorporated into the workplace.

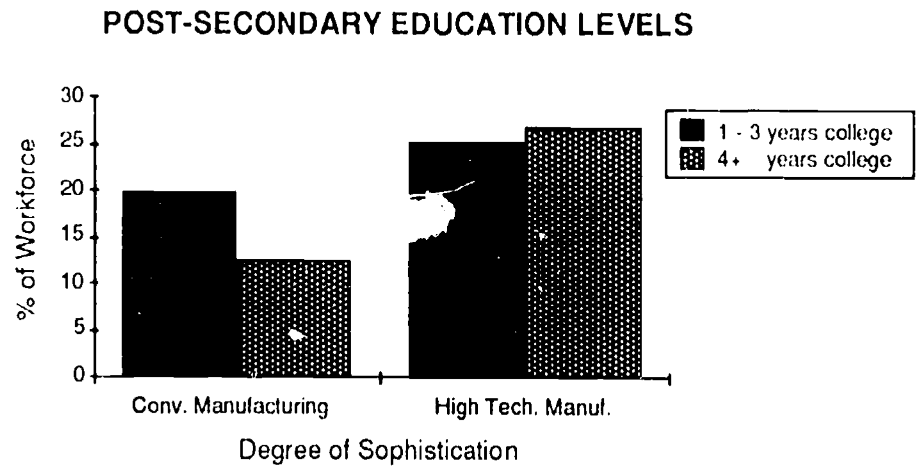

Figure 8. Post-Secondary Education Levels Needed
Source: Grubb, (1984)

View 3: Sophisticated technology decreases the overall skill requirements of the workforce. The third view suggests that advances in technology will actually decrease the overall skill requirements needed by the workforce (Bartel & Lichtenberg, 1987; Faddis, Ashley, & Abram, 1982; Rumberger, 1984, 1987). While the characteristics of future jobs will likely change the overall skill requirements are expected to decrease according to this view. A general assumption regarding the impact of technology on skill requirements is that as technology advances, the skills needed to work with technology also increases. This view appears to be developed by many people as they interact with the technological world. For example, many people believe that a computerized word processor is a highly technical tool that is much more complex than the manual or electric typewriters with which they were comfortable. Another example involves the many backyard mechanics who at one time were able to repair their own automobiles. Because of the advances in technology, these mechanically inclined individuals are having considerable difficulty comprehending the new technological systems found

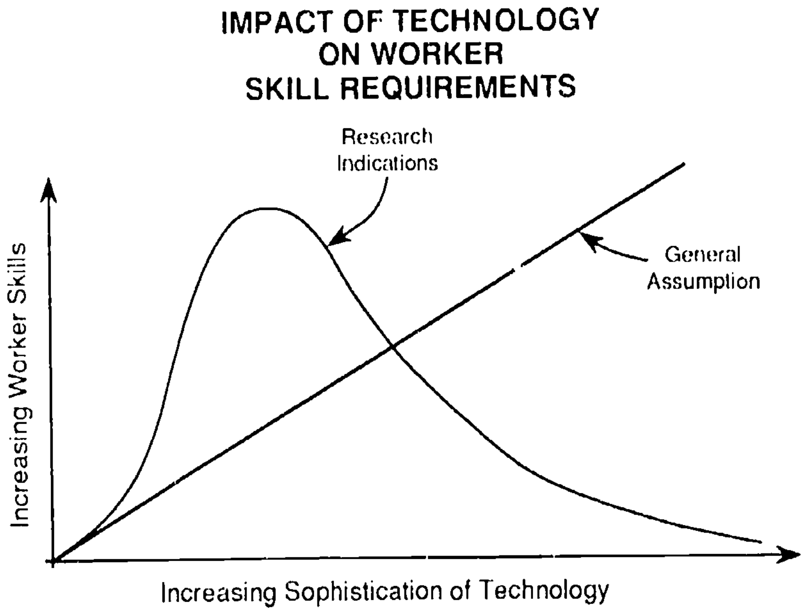

Figure 9. Impact of Technology on Worker Skills.
Source: Bright, (1966)

in late model vehicles.

As technology advances it certainly appears as though the skill requirements needed to work with those technologies also increase. This statement is only partly true. Research indicates that the impact of technology on worker skill requirements is very different from the general assumption (see Figure 9). While the skill requirements do increase initially, as a technology is further developed and refined, the skill requirements needed to use that technology actually decrease. An example of this phenomenon is the computer. When the computer was originally invented, it was a very complex machine that was difficult to use. Following the development of technologies that lead to the production of transistors and then integrated circuits, the computer became a smaller, more powerful machine that was immensely more complex than the original computer. However, while the computer became much more sophisticated, it also became more "user friendly." Refinements in computer technology have led to the development of a machine that is relatively easy to learn how to use. The trend to simplify the use of equipment results in a deskilling of the workforce because the technology reduces the need for much of the mental and physical work needed to conduct daily work tasks. Other examples of this deskilling phenomenon can be found in computer programming, automated production, printing, clerical work, and machining.

These three views present differing projections of the impact of technology on the skill requirements of the workforce. Based on the above discussion, several conclusions can be made. First, technology has resulted in a decrease in the skill requirements of some jobs. Second, technology has resulted in an increase in the skill requirements of some jobs. Overall, however, it appears as though there has been little change in the *average* skill requirements of jobs. In a recent study of 200 individual case studies, Flynn (1985) found that while some workers' skill requirements have been upgraded, other workers' skill requirements have been downgraded. It appears as though the overall effect of technology on the skill requirements is small. On an individual basis, however, the effect of technology on skill requirements appears to be quite drastic.

SECTION 4
THE WORKFORCE OF THE FUTURE

While technology has made some tasks easier to complete, it has also made other tasks more difficult. Rather than attempt to identify the overall impact of technology on the workforce by examining increases and decreases in skill requirements, more relevant information can be obtained by identifying the specific skills and competencies that are needed by the workforce of the future.

A major objective of the Sophisticated Technology Project was the completion of an investigation of the impact of advanced technologies on the workforce. Two activities were planned and completed to address this objective:

1. A review of recent workforce competency literature.
2. A series of interviews of individuals from various businesses in Illinois, Michigan, and Ohio.

The following sections contain a review and analysis of recent workforce competency literature and a summary of the interviews that were conducted.

Summary of Workforce Competency Reports

Since 1985, several state and national reports have appeared which (a) predict the nature of the workforce of the future based on labor market statistics, (b) suggest skills and competencies that will be needed by the workforce if the United States is to regain its competitive advantage, and (c) offer recommendations regarding the education and training that is needed to prepare the worker of the future. These reports have gained a great deal of national attention and seem to be adding fuel to the educational reform movement of the 1980s. Consequently, vocational educators need to become thoroughly familiar with the contents of these reports, especially the skills and competencies that are identified and the recommendations for education and training. The following is a summary and analysis of five state and national workforce projection reports which seem to have the greatest potential to significantly impact the preparation of future workers.

The five reports chosen for analysis were:

- Employability Skills Task Force. (1988). *Report to the Governor's Commission on Jobs and Economic Development* (A Michigan employability profile). Detroit, MI: Governor's Commission on Jobs and Economic Development.
- A series of articles from the Southern Growth Policies Board's 1986 Commission on the Future of the South.
- Carnevale, A. P., Gainer, L. J., & Meltzer, A. S. (1988). *Workforce Basics: The skills employers want.* Washington, DC: U. S. Department of Labor Employment and Training Administration & The American Society for Training and Development.
- McLaughlin, A., Bennett, W. J., & Verity, C. W. (1988). *Building a quality workforce.* Washington, DC: U. S. Department of Labor, U. S. Department of Education, U. S. Department of Commerce.
- Johnston, W. B. & Packer, A. H. (1987). *Workforce 2000: Work and workers for the 21st century.* Indianapolis, IN: Hudson Institute.

The stated and implied recommendations of the five workforce competency reports were summarized into seventeen categories. As shown in Figure 10, the categories are listed in descending order beginning with those mentioned by all of the sources. The remainder of this section is devoted to an explanation of the seventeen recommended skills and competencies.

Reading & Comprehension Skills

As technology advances, almost every occupation tends to becomes more technical in nature. A major characteristic of technical occupations is that the written material that accompa-

Desired Competency/Skill \ Workforce Projection Report	Michigan Employability Task Force	Southern Growth Policies Board	Workplace Basics (ASTD/DOL)	Building a Quality Workforce (DOL, ED, DOC)	Workforce 2000 (Hudson Institute)
Reading & Comprehension Skills	●	●	●	●	●
Written & Oral Communication Skills	●	●	●	●	●
Thinking, Problem Solving, & Decision Making Skills	●	●	●	●	●
Computation Skills	●	●	●	●	●
Technical Skills	●	●	○	●	○
Flexibility	○	●	○	●	●
Ability to Learn/ Adaptability	●	●	●	●	
Positive Attitude, Motivation & Self Direction	●	●	●	●	
Teamwork & Interpersonal Skills	●	○	●	●	
Creativity	●	●	●		
Understanding of the "Big Picture"	○	●	●		
Good Work Habits	○	○		●	
Multicultural Skills	●			●	
Scientific Knowledge	●	●			
Career & Personal Development	●		●		

● Explicitly stated in the report
○ Implied

Figure 10. Summary of Workforce Competency Reports.

nies the new equipment and processes is also more technical which makes the material much more difficult to read. In addition, more and more occupations involve interaction with computers and complex computerized equipment. As a result, more and more workers in the future will need to be able to read and comprehend at a much higher level than the present workforce. According to Mikulecky (1984) approximately 70% of the written material used in a cross section of jobs requires at least a high school reading level. The vast majority of the employers contacted as a part of the *Building a Quality Workforce* (McLaughlin, Bennett, & Verity, 1988) study agreed that all workers need at least an eighth grade reading level and that most technical occupations require at least a 12th grade reading level.

All of the reports mentioned that there is a growing discrepancy between the needs of business and the reading and comprehension skills of the current workforce. However, it should be pointed out that the majority of the current workforce is literate. A major problem identified by the *Workforce Basics* report (Carnevale, Gainer, & Meltzer, 1988) is that reading skills are often taught in isolation of real-world activities for the purpose of learning facts. They contend,

> Reading tasks on the job are different. They require the reader to be analytical, to summarize information, and to monitor one's own comprehension of the reading task. This is an interpretive approach that requires the reader to have active involvement with the reading task. From the employers perspective, basic training in reading should focus on teaching reading processes for locations of information and for using higher level thinking strategies to solve problems (Carnevale, Gainer, & Meltzer, 1988, p. 10).

Written and Oral Communications Skills

Even in the factories of the past, where the majority of the workers spent the entire day working in isolation at some repetitive task, workers spent a considerable amount of time communicating with others. In many of today's occupations (e.g., word processing and telephone operators), communication is the central activity. The ability to communicate effectively was, and still is, essential for productive employment. In the future more workers will be asked to work in teams, deal directly with customers, and participate in decision-making. All of these changes increase the importance of the ability to speak and write effectively. In addition to effectively communicating with others, the changing workplace also requires the ability to communicate with a computer or some other electronic device.

Thinking, Problem-Solving, and Decision-Making Skills

The workforce reports unanimously agree that employers want workers who can think on the job, solve complex problems, and make decisions. In the manufacturing businesses of the past, it was most important for supervisors and managers to have these skills. Today, however, many more businesses and industries are involving their workers in the decision-making process through quality circles and production teams. In many technical occupations, keen analytical skills are needed because a considerable amount of time is spent troubleshooting and repairing complex electronic equipment.

In an effort to increase productivity, quality, and the ability to react quickly to problems, many businesses and industries are beginning to encourage decision-making at the production level, thus flattening the corporate structure and decreasing the need for middle management.

Bank tellers are becoming financial consultants rather than transaction handlers. Biomedical equipment technicians, in addition to maintaining medical equipment, learn how to operate new equipment and then train others in its proper operation. Workers in a modern automobile factory are members of teams that are responsible for assembly, quality control, and evaluation of the production process, and are also asked to suggest ways to improve the production process. These examples serve to show that a growing proportion of the workforce of the future will need to be able to think clearly and critically, solve complex problems, troubleshoot, and make decisions.

Computation Skills

All of the reports agree that the workforce of the future must be proficient in basic computational skills. As a minimum, every worker should be able to do basic arithmetic, which includes working with fractions, decimals, proportions, and measurements. As occupations become more technical, skill with algebra, geometry, statistics, and trigonometry becomes essential.

In the past, machinists needed to know algebra and trigonometry to operate the machines and produce complex parts. Today, machinists working with Computer Numerical Control (CNC) machines or Fully-Automated Manufacturing (FAM) are required to know machine programming, the Cartesian coordinate system, and statistical process control.

Technical Skills

Whereas technical skills were implied in all of the reports, it was mentioned specifically in only three of them. Educational reformers of the 1980s, many of whom believe that vocational education does not belong in public elementary and secondary education, would have us believe that businesses want graduates to have only strong basic skills and that each business will provide technical training for their workers (U. S. Department of Education, 1986). However, the evidence does not support that contention.

According to Carnevale and Schulz (1988), only 36% of all employees ever receive formal or informal on-the-job training. They point out that the majority of the on-the-job training goes to professionals, that is, those workers with the highest education levels. Carnevale, Gainer, and Meltzer (1988) report that research shows that workers who have only a high school diploma are not likely to receive any on-the-job training, while those with a two-year degree are 20% more likely, and those with a college degree are 50% more likely to receive on-the-job training. In addition, Gray (1989) points out that the majority of entry level workers are younger workers who go to work for smaller firms (i.e., with less than 100 employees) which usually are not able to provide formal training or educational assistance.

Several of the reports mention that other countries are able to get a product from the idea stage to production much quicker than the United States. Carnevale and Schulz (1988) contend that this is partially due to the amount of training given to our scientists and other professionals. They argue that business/industry must begin providing additional training at the blue-collar or technician level if there is to be an improvement in the ability to produce products.

Finally, technical skills are essential because they facilitate the acquisition of additional skills. On a very practical level, employers tend to select those workers who already have well-developed technical skills to learn and use new equipment and processes. When CNC machining is introduced into a company, it is very common for the company to select their best machinists to learn the new production process. In an office, secretaries who possess solid word processing skills are often selected to learn desktop publishing. When one considers how individuals develop expertise, having some technical skills makes it easier to learn new technical skills. Consequently, technical skills are more important than many education reformers would suggest. What still remains to be determined is how and when technical skills should be taught and the role of vocational education in that task.

Flexibility

The days of graduating from high school and going to work for a business or industry, then retiring from that same company some 35 to 40 years later are gone. Today, and in the future, it is more likely that individuals will change jobs and careers several times in their lifetime. The previous decade has witnessed the emergence of new occupations, the alteration of others, and the demise of still others. The workforce reports contend that the competitiveness of the U. S. is contingent upon the ability of the workforce to quickly adjust to these situations.

Workers also need to be flexible enough to deal with the constant and rapid changes in existing technology and the emergence of new technologies. New equipment and processes which are being developed at an increasing rate, new and more products/services, and variations in existing products/services will require a workforce that is flexible and can change quickly.

The workforce of the future must also contend with a wider variety of working arrangements. Many manufacturing businesses are using production teams where workers from several different areas within the company work together to produce a product. Advances in technology have also allowed the duties of several jobs to be performed by one person. For example, the introduction of computers in banks has made it possible for tellers to provide several services to the customer which, prior to that time, were provided by other workers. Technology is making it possible for some jobs to be eliminated, while increasing the range of skills needed to do those jobs that remain. Consequently, employers want workers who are flexible, who can learn quickly, and who can adapt to a wide variety of situations.

Ability to Learn/Adaptability

According to four of the five reports, flexibility, adaptability, productivity, and competitiveness are dependent upon the workforce's ability to learn. *Workplace Basics* (Carnevale, Gainer, & Meltzer, 1988) maintains that the ability to learn is the "most basic of all skills" (p. 8). They contend that this skill is the foundation that will make the successful acquisition of other basic skills possible. *Building a Quality Workforce* (McLaughlin, Bennett, & Verity, 1988) calls for workers who can "figure out what they need to know and how to find that information" (p. 16) The Southern Growth Policies Board goes so far as to imply that learning how to learn ensures the ability to change.

There seems to be little doubt that being able to learn and adapt to change are essential skills for the workforce of the future. Workers must be able to learn on the job quickly as technologies, products, and services change. Workers must also be willing and able to learn new jobs as old ones become obsolete and are replaced. However, it needs to be made explicit that employers want employees that are able to learn, not to continue improving their basic skills, but to improve their technical skills.

Positive Attitude, Motivation and Self-Direction

In order for American businesses/industries to improve productivity and thereby regain their worldwide competitiveness, the majority of the workforce reports contend that the workforce must be motivated and self-directed. Workers with a positive attitude who are willing to determine what needs to be done and then take the initiative to get the job done well are needed if America is to regain its competitiveness in the world market. Of course, this type of worker has always been sought by business and industry. However, these reports contend that these skills are currently needed and will become even more important in the future.

Teamwork and Interpersonal Skills

With the increased use of production teams in manufacturing firms, with the increased need to share information in many occupational areas, and with an increase in the number of service workers and others who deal directly with customers, there is a growing need for entry-level employees to possess strong interpersonal skills. Workers must be able to communicate and work effectively with their colleagues and supervisors.

Manufacturers want employees who can work together and have the interpersonal skills to make a contribution to the team. According to Carnevale, Gainer, and Meltzer (1988), "whenever people work together, successful interaction depends upon effective interpersonal skills, focused negotiations, and a sense of group purpose. The quality of these three factors defines and controls working relationships" (p. 14).

Creativity

The Michigan Employability Skills Task Force (1988) calls for workers who have the ability to use information, knowledge, and beliefs to generate unique solutions to problems. Rosenfeld (1986), writing for the Southern Growth Policies Board, argues that employees are needed who are able to use their knowledge to contribute to innovation. Business and industry has always needed "idea people", but today it is even more important for workers to have the expertise to put their ideas into practice.

Understanding the "Big Picture"

If bank tellers are going to function as "frontline" financial consultants, if productions workers are going to work in teams, and if employers want workers who are flexible and can perform a wide variety of jobs, then workers need to have an understanding of the "big picture" (i.e., how a product or service gets from idea to delivery, and how the company works). Carnevale, Gainer, and Meltzer (1988) suggest that in order "to be effective in an organization, employees need a sense of the workings of the organization and how their actions affect organizational and strategic objectives" (p. 15). Rosenfeld (1986) emphatically states that "modern businesses seek the individual who, in addition to technical competence, is able to understand how the entire production and business systems fit together" (p. 2).

Good Work Habits

Little needs to be said about these skills which have been highly valued by employers for as long as there have been employers and employees. Employers want employees who are reliable, trustworthy, capable of working independently, and who come to work regularly and on time. In this age of intense competition, American business cannot afford the extra expense of repeatedly replacing bad employees and training new ones. They also cannot afford the reduced productivity caused by workers with bad work habits.

Multicultural Skills

Each of the reports points out that American businesses/industries are dealing with a global market rather than a national market. Raw materials, capital, labor, products, and service are available on the world market from a variety of sources. Prospective buyers are now in a position to purchase from a supplier, anywhere in the world, who has the best product/service at the lowest price. In addition, many companies have entered into joint ventures with overseas companies. This often results in the two companies sharing ideas, techniques, and even employees. Consequently, two of the workforce reports recommend that employees have an understanding and appreciation of other cultures so they can deal effectively with an international market and joint ventures.

Career and Personal Development

In the future, workers will need to have the knowledge and skills to effectively direct their own careers. With an increasing number of job and career changes, and with the transience of many jobs and companies, it will be more important in the future for employees to take it upon themselves to direct their own careers instead of relying on the company to determine what they need.

Summary of Project Interviews

The preceding summary was based on several national and state reports, all of which were from sources outside Illinois. Undoubtedly, much of what has been written about the workforce of the future does apply to Illinois. However, the degree to which these findings and recommendations do apply to Illinois is dependent upon the degree to which the situation in Illinois is similar to these other areas. To help alleviate this lack of information about the needs of the future workforce in Illinois, a series of interviews with a wide variety of businesses and industries were conducted. The following is a summary of the methods used to conduct this study and the themes that emerged from the data.

Method

The subjects for this study included personnel managers, personnel specialists, department managers, general managers, business owners, and corporate level personnel. A total of 36 interviews were conducted. The decision to focus on personnel-oriented managers rather than training specialists was based on the assumption that personnel managers/specialists would have the best understanding of the entry-level employment requirements for all of the jobs within a particular company and because they are concerned with job qualifications and not necessarily the amelioration of deficiencies in the existing workforce which is the concern of most training managers.

A major concern of this study was to gather data from as many technological areas as possible. The businesses and industries that were interviewed included food production, automobile manufacturing, machining and fabrication, heavy equipment manufacturing, pharmaceutical manufacturing and research, biotechnology research and development, agricultural research and development, agricultural production, manufacturing training and production consultants, aircraft simulators manufacturing, photocopier manufacturing, plastics manufacturing, financial institutions, electronic controls design and manufacturing, computer software developers, commercial printers and newspapers, coal mining, a computer disk manufacturer, a biochemistry laboratory, a utility company, a foundry, and a hospital. Businesses and industries were chosen to ensure representation in each of the four classifications of technologies (i.e., physical, biological, informational, and organizational). The following set of questions was developed to guide the interviews:

- Do you currently employ technicians (a definition was provided)?
- What are the general duties of these positions?
- What skills and competencies are needed to perform these jobs?
- How do individuals get these skills and competencies?
- What changes have taken place in these occupations in the past five years?
- Does your company provide training? How much, to whom, and what type?
- Is your company having any problems finding qualified people for these positions?
- Does your company use outside sources of training (e.g., area high schools and community colleges)?

Whenever possible the interviews were recorded and transcripts were typed. Field notes were also taken during and after the interviews. The data was analyzed to identify any prevalent themes regarding the skills needed by workers in the future.

General Themes

The growing need for computer skills. There was almost a unanimous agreement that employees need basic computer skills. Secretaries are now using word processors. Almost every bank employee uses a computer in some aspect of their work. Production workers interact with the computers that control the machinery and store production data. Hospital employees use computers to access and record patient information. While there are many jobs which still do not involve computers, every business that was interviewed had significantly increased their use of computers in almost every department.

A focus on specific job qualifications. Personnel managers tend to focus on the level of education and the experiences of the applicants. In most cases they seemed to assume that the successful candidate would possess solid basic skills. Personnel managers are constrained by company policies and the wishes of the department managers they have to satisfy. Consequently, personnel managers were far more concerned about hiring the applicant with the most relevant education and experience. One personnel manager in a large information company stated that he would be hard pressed to recommend hiring a person who did not possess the qualifications listed in the job description even though that person might have very solid skills.

It was also noted that larger companies were more interested in hiring employees who have solid basic skills while smaller firms seemed to desire individuals with strong job-specific skills. It was also interesting to note that companies who were involved in pre-employment testing were much more concerned about basic skills than companies who did not have pre-employment testing. Technical skills were irrelevant if the applicant could not pass the basic skills test.

Discrepancy in recommendations. As mentioned by Rosenfeld (1986), there was a discrepancy in the information received from personnel managers and that received from training managers. Personnel managers were far more concerned about specific job requirements while training managers seemed to focus on correcting deficiencies in the existing workforce. Consequently, when considering the recommendations of the workforce projection and needs assessment reports, it is essential that it be noted which individuals are providing the data.

Promotion from within. Many companies hire individuals for basic entry level positions, then promote from within. This approach gives the company an opportunity to evaluate the employee before they invest additional time, effort, and money. Employees who perform well at that level are promoted and are provided additional training as needed.

Changes occur slowly. Companies are much slower to adopt new equipment and processes than the popular media would have the American public believe. For the most part, the employers that were interviewed would implement new equipment and processes when it became profitable to do so. Consequently, it seemed that the majority of the employers, especially the smaller ones, were still using mature technologies even though sophisticated technologies were available.

There were two distinct areas that were changing at a much greater rate than the rest. Biotechnology research and development, and the medical fields seemed to change fastest and most often as new techniques and equipment develop. Occupations in these fields utilize the latest equipment and devote a great deal of time and energy to training.

Diversity within fields. Even within the same field, no two employers are alike. Differences in management philosophies, styles, and production techniques makes it very difficult to make broad generalizations about the changes taking place with a particular field, much less the entire workforce.

Changing skills and competencies. The interviews did support the general contention that the required technical skills were changing and that the changes were going to continue. Occupations are different today, due to technological changes, than they were five years ago. A major change seemed to be a trend away from a reliance on physical skills and human power, to mental skills and machine power. Employees are doing more mental work and less physical labor.

Employers provide formal and informal training. There was a wide variety of programs used to deliver training, however, almost all of the employers were providing some sort of on-the-job training. The larger companies were more likely to have formal training programs and were more likely to provide educational assistance in the form of reimbursement for successful completion of college courses. Smaller companies tended to rely on in-house, on-the-job training programs; a great deal of which is provided by the vendors of new equipment.

There did not seem to be any consensus among the employers with regard to the use of community colleges to provide training. Some employers were using community colleges a great deal both through customized training and through regularly scheduled courses. The opposite situation was also prevalent. Some of the employers found community colleges difficult to work with and uninterested in providing the kind of training the company needed in a format the company could use.

Conclusions

Based on the information obtained through the synthesis of the workforce reports and the interviews with business and industry representatives, several general conclusions regarding the competencies of the workforce of the future can be made.

1. Employers need employees who possess solid basics skills. Whereas these skills were essential, in the past, for promotion beyond entry-level positions, these skills have and will continue to become more important at the entry-level.
2. Employers need employees who possess solid technical skills. As stated by a utility company representative, "To be considered for a junior draftsman position, a person must have completed a two-year drafting program. They will then receive two more years of training on our system before they can become a draftsman." In the medical fields, most of the occupations require a certificate from a training program and state or local licensure. As stated by Gray (1989), it seems that what employers mean by basic skills is somewhat different from what academicians mean.
3. Vocational education is still very much needed in the United States. What is unclear is when, where, and by whom vocational education needs to be delivered. What

is quite clear is that a large portion of vocational education programs have been guilty of focusing exclusively on job specific skills and have ignored some of the other non-technical skills that are necessary for successful employment.

4. Almost everyone graduating from high school today and in the future needs to be "computer literate." Computers are already a major part of many occupations and their use will undoubtedly continue to increase. This doesn't mean that every student needs to be a computer programmer. Every student needs to know how to use a computer and how to perform basic applications such as word processing, database applications, and spreadsheets.
5. In the future, employees will spend more time in training. While less time may be spent in training to secure an entry level position, employees in the future will need more training to upgrade their knowledge and skills as technology changes. In addition, employees will need more retraining as they change jobs and careers in the future.
6. The employment picture is a complex one and will require additional and repeated study if the United States is to prepare adequately for the future.

SECTION 5

EDUCATION TO PREPARE THE WORKFORCE OF THE FUTURE

When addressing the issue of technological change and the implications for education at an annual convention of the Department of Rural Education and its Division of County and Intermediate Unit Superintendents, Venn (1963) stated, "... we are turning out too many young people into a technological age unequipped with the tools they need to live and work effectively." The significance of this statement lies in the fact that Venn's presentation took place over 25 years ago.

Secondary and Post-Secondary Vocational Programs

Vocational education as a separate and distinctive curriculum to furnish the necessary tools needed to live and work effectively resulted from the passing of the Smith-Hughes Act in 1917. The Smith-Hughes Act, by appropriating over 7 million dollars per year to be used for preparing young people for immediate employment, established vocational education as a national priority.

Few structural and programmatic changes occurred in vocational education from 1917 through the middle of the century. However, during the 1950s, new forecasts of increased industrial automation led people to rethink the purposes of vocational education. Congress passed the National Defense Education Act (NDEA) in 1957 after the launching of the Sputnik satellite in an attempt to diminish existing shortages of technicians. This act allocated funds for the training of technicians for occupations requiring scientific knowledge and authorized funds for specialized technical institutes and area vocational centers to deliver more specialized vocational education programs (Rosenfeld, 1986).

National priorities changed again in the early 1960s as many legislators believed that the effects of the NDEA were reaching only a small number of vocational education students. The entire vocational education initiative came under review when President Kennedy requested that the Secretary of Health, Education, and Welfare appoint an advisory body, called the "Panel of Consultants on Vocational Education," to evaluate and recommend changes for vocational education. The Vocational Education Act of 1963 resulted from this Panel of Consultants on Vocational Education. Many of the two year post-secondary technical institutes became eligible for, and received, federal funds during this time because many of the technical occupations required skills and knowledge beyond that provided at the secondary level.

The development of these two year post-secondary programs should have led to program articulation between the high schools and the technical institutes. Instead, the high schools and post-secondary institutions often competed for limited resources. As a result, high school programs became even more specialized in an attempt to prepare students for technical occupations. Colleges concurrently began placing emphasis on office occupations and trade and industrial programs and paid too little attention to the preparation of technicians (Rosenfeld, 1986).

The 1980s have not been without vocational education reform movements. Federal vocational education policy changed once again when the Carl D. Perkins Vocational Education Act was passed in 1984. For the first time, vocational education explicitly addressed and responded to the impacts of technological change. The Perkins Act directed states to plan for technological changes in the economy, to orchestrate programs with new industries dependent on a technically competent workforce, to prepare people for technological changes in the workplace using technologically advanced equipment, and to assess their performance in meeting technological needs.

The Perkins Act required that a state, before receiving federal funds, be evaluated in terms of specific criteria, which include the pertinence of programs to the workplace and to new and emerging industries and the technological and educational quality of vocational curricula, equipment, and instructional materials to enable vocational students and instructors to meet the challenges of increased technological demands of the workplace.

Of the Perkins Act's 24 authorized uses, those which relate to technological changes include:

- the improvement of vocational education programs including high-technology programs involving industry-education partnerships,
- exemplary and innovative programs which stress new and emerging technologies, and
- the acquisition of high-technology equipment for vocational education programs.

Recent federal legislation has attempted to define vocational education's role in preparing the worker of the future. Have vocational education programs effectively adapted to the changing skills and competencies that are desired by employers? As one examines the curriculum of vocational classrooms, it is not clear that the desired knowledge and skills are being provided. One can find numerous classrooms where these desired skills are not being addressed. The discrepancy between industry's needs and vocational program offerings was echoed in a recent publication from the National Alliance of Business (1988).

Vocational education programs need to become more responsive to the demands of a changing workplace. While employers indicate they need entry level employees with more than the technical training offered by most vocational education programs, many of these programs continue to concentrate on highly specific job skill training, often conducted with obsolete equipment using outdated methods that are no longer compatible with current processes and practices. (National Alliance of Business, 1988)

While the efforts to change vocational education programs to better prepare the worker of the future have had a limited overall impact, several exemplary programs do exist. It is these exemplary vocational education programs that can become the models for other programs in order to adequately meet the challenge of preparing the worker of the future. The following section describes the exemplary programs that appear to provide appropriate vocational training to meet future workforce requirements.

Core-Plus-Specialty Curriculum Design

A number of community colleges have been trying to find innovative curricular designs to become more efficient in providing the pre-requisite foundation courses and providing greater opportunities for technical specialization. The *core-plus-specialty* design allows a student to gain the basic knowledge and skills required in a variety of specific occupations and at the same time see how a selected occupation relates to others within the same setting. This curriculum design has several advantages for the college as well. It allows colleges to support smaller enrollments in the specialty courses by having larger enrollments within the technical core courses. Another advantage to the college using the core-plus-specialty curriculum design is it's ability to cross train or retrain individuals who have previously completed the core requirements.

The core-plus specialty program design can foster cooperative efforts among community colleges within a geographic region. The cost of implementing specialties within each cluster is generating articulation efforts between community colleges to share resources and develop inter-community college curriculum arrangements. This type of "1+1" cooperative effort allows students to transfer from one college to another after completing the general and technical core requirements thereby enabling them to complete their desired specialty.

Tech-Prep 2+2

The need to provide an appropriate education and training for the large percentage of our high school students who will either not attend college or will attend college but not graduate has recently been addressed. According to Parnell (1985), three out of four high school students belong to this group identified as the "neglected majority".

In an attempt to better serve the neglected majority, many high school and community college systems throughout the country have joined efforts to develop 2 + 2 programs. In this type of arrangement, students select the tech-prep option in their junior year of high school and continue for four years in a structured and coordinated high school/community college curriculum. Federal support for this type of articulation is provided for in the revised Perkins Act of 1989.

Advanced Technology Centers

Advanced Technology Centers (ATCs) have emerged as a viable resource for technology information, education, and training needs. To date, over 40 ATCs provide their resources to business and industry. According to the National Coalition of Advanced Technology Centers, Advanced Technology Centers are aggressively rebuilding the technical education and skill base of America's workforce while helping companies expand and compete by using the best and most up-to-date available technology.

The NCATC has identified the following seven functions of ATCs:

1. Identify new applications of technology for specific industries.
2. Demonstrate the advantages of new technological applications.
3. Prepare workers to integrate advanced equipment and production processes.
4. Determine the feasibility and efficiency of accommodating advanced technologies.
5. Assist in the acquisition, installation, and operation of equipment.
6. Provide the training required to install, operate, and maintain the systems.
7. Equip managers and supervisors to function in new technological and organizational environments.

The Core-Plus-Specialty curriculum model, the Tech-Prep 2+2 model, and the Advanced Technology Centers are only a few of the exemplary attempts to extenuate the expanding gap between the needs of the workforce and the ability of vocational education to meet those needs. Further investigation into these types of programs is needed to better determine their utility for meeting the needs of the changing workforce.

SECTION 6

RECOMMENDATIONS FOR VOCATIONAL EDUCATION

Based on the findings of this project, several recommendations for the future direction of vocational education in the State of Illinois can be made. Each of the following recommendations were determined through the analysis of the literature and through the data collected during interviews and other interactions with business and industry representatives.

Recommendation 1

Decisions to develop new educational programs in sophisticated technology areas must be made carefully and be based on current and projected employment demands.

When identifying the characteristics of an appropriate program, one must proceed with caution. What is appropriate for a program that meets the needs of Portland, Oregon may not be appropriate for meeting the needs of Bloomington, Illinois. Grubb (1984), suggests that inappropriate planning often results in schools jumping on the high-tech bandwagon and developing new programs prior to an exhaustive needs assessment.

A thorough needs assessment process must be developed and followed prior to the development of new vocational programs in sophisticated technology areas. This needs assessment must examine the current and future needs of the private sector in the local area so the programs that are developed will be appropriate for their location. Another benefit to be derived from local needs assessment activities will be partnerships between businesses and the educational institution and better placement opportunities for program graduates.

Recommendation 2

The Illinois State Board of Education and the Illinois Department of Labor should work cooperatively to develop a system to project future trends in employment needs. This system should be designed to ensure that it is capable of reacting to rapid changes in the workforce.

The available workforce projection literature tends to focus on manufacturing industries and is from sources outside of Illinois. Additional research is needed to determine the occupational needs of the workforce in Illinois as well as the skills and competencies needed for those occupations. Accurate employment projections for Illinois will greatly enhance the ability of vocational programs to meet the economic development needs of the state and to provide up-to-date services to students.

Recommendation 3

Quality sophisticated technology-oriented vocational curricula must be designed and delivered to help students develop the competencies and skills identified by business and industry.

An evaluation of the existing community college programs, facilities, and faculty in the sophisticated technology content areas should be completed to determine the extent to which current programs provide or are capable of providing the type of education and training that will effectively prepare individuals for the workforce of the future.

Technical skills are needed as much now as they ever were. However, it is also clear that generic, basic skills are increasing in importance. Effective vocational programs in the future will be those that provide students with both the specific technical skills that are needed for employment and the generalizable, basic skills that enhance an individual's ability to learn and adapt to a changing work environment.

Recommendation 4

Partnerships between vocational programs and local businesses and industries must be established and developed.

Quality vocational programs build solid bridges between their programs and the businesses and industries in their community. Advanced Technology Centers are good examples where partnerships have paid off by helping schools obtain state of the art equipment to train current and future workers for specific environments and to validate the content of the vocational curriculum.

Recommendation 5

Articulation must exist between vocational programs at the high school level and at the post-secondary level.

Many programs have set up successful partnerships between secondary and post-secondary facilities to cut down on equipment cost to the district as well as streamline a student's path to graduation. These efforts must continue to be cloned.

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Database Search Directions

The following references have been identified and obtained by the Sophisticated Technologies Project. The database currently contains 155 references related to sophisticated technologies, the future workforce, and vocational education. A set of key words have been used to classify each of the references to facilitate the location of desirable readings according to their content. The following keywords have been used:

> biotechnology, definition, education, future, impacts, informational, legislation, physical, science, skills, technology, training, workforce, economics

The references have also been put into a computer database which may be accessed through the reference database and bibliography maker "EndNote." EndNote is available from Niles & Associates, 2200 Powell, Suite 765, Emeryville, CA 94608; (415) 655-6666. This database system will allow the user to type in any of the keywords and will select those references which match the request.

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