DOCUMENT RESUME

ED 286 737 SE 048 575

AUTHOR	Fleming, Reg
TITLE	Technological Literacy. A Common Essential Learning for Saskatchewan Students.
INSTITUTION	Saskatchewan Univ., Saskatoon. Dept. of Curriculum Studies.
SPONS AGENCY	Saskatchewan Dept. of Education, Regina.
PUB DATE	Jul 87
NOTE	68p.; Study completed for the Core Curriculum Investigation Project.
PUB TYPE	Reports - Descriptive (141)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Elementary School Mathematics; Elementary School Science; Elementary Secondary Education; *Foreign Countries; Health; *Interdisciplinary Approach; Language Arts; Mathematics Education; *Science and Society; Science Education; Secondary School Mathematics; Secondary School Science; *Social Studies; *State Departments of Education; *Technological Literacy
IDENTIFIERS	Canada; *Saskatchewan

ABSTRACT

In 1986, after a thorough review of educational goals for Saskatchewan (Canada) schools, the Saskatchewan Department of Education published its findings and recommendations. A key recommendation was to incorporate six "common essential learnings" categories into all courses of study offered in Saskatchewan schools. One of these six categories, that of "technological literacy," is the focus of this paper. Within the text of the paper a number of variables influencing the achievement of this goal are addressed, including: (1) a meaning for literacy; (2) a meaning for technology; (3) technological literacy; (4) technology and science (including discussions on contemporary views of science and technology, and research and development); (5) technology and social change; (6) technological literacy and decision making; (7) technological literacy and the computer; and (8) technological literacy and other curricular frameworks. General conclusions and recommendations are also presented, including specific recommendations on the incorporation of technology into language arts, social studies, science, mathematics, and health. Included in the appendix is a scope and sequence chart which cross-references various technological themes into elementary, middle, and high school settings. (TW)

TECHNOLOGICAL LITERACY

A Common Essential Learning for
Saskatchewan Students

Reg Fleming, Ph.D.

Department of Curriculum Studies
College of Education
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

July, 1987

This paper was written under contract for Saskatchewan Education. The views expressed herein are those of the author and do not necessarily represent the views of Saskatchewan Education.

TABLE OF CONTENTS

Preface . . . . (i)

Introduction 1

A Meaning for Literacy 1

A Meaning for Technology 2

Technological Literacy 4

Technology and Science 6

Contemporary view of science and technology 6

The relationship between science and technology 9

Research and development (R & D) 12

Technology and Social Change 13

Technological Literacy and Decision Making 18

Technological Literacy and the Computer 20

Technological Literacy and Curricular Frameworks 25

Conclusions and Recommendations 34

General Conclusions and Recommendations 34

Subject Area Recommendations 44

Scope and Sequence Charts 50

References 52

Bibliography 54

Appendix A 56

PREFACE

In 1986, after a thorough review of educational goals for Saskatchewan schools was completed, the Department of Education published its findings and recommendations in the report Program Policy Proposals. A key recommendation was to incorporate the following six categories of common essential learnings into all courses of study offered in Saskatchewan schools: communication skills, creative and critical thinking, independent learning skills, numerical and quantitative literacy, personal and social skills and values and technological literacy.

Each category includes those skills, attitudes, and processes deemed necessary for functioning in society no matter what students choose to do after completing their elementary and secondary school education. A major responsibility of schools will be to ensure that all graduates are proficient in these common essential learnings regardless of their program of study.

The report offered only a small number of examples of what each category might entail. For technological literacy, for example, the major focus is on the interaction between science, technology, and society. In this sense, the report is in agreement with several of the recommendations made in the Science Council of Canada's Report #36, Science for Every Student, which strongly advises that science curricula incorporate this focus also. The proposal to include these interactions, where feasible, in all core subjects is an exciting one indeed.

The focus of this paper will be on the common essential learning, technological literacy.

Technological Literacy

Introduction

> Hephaestus, the Greek god of fire and metalworking, had a pronounced limp. Entrusted with the development and maintenance of many key technologies, Hephaestus was responsible for keeping society running smoothly and perfectly. Yet he was, ironically, the only imperfect member of the pantheon of classical gods . . . As in Hephaestus himself, the power and versatility of technology are often marred by crippling defects (Norman, 1981, pp 15-16).

It is well known that during the fifties and early sixties, a sense of technological optimism reigned. This optimism was based essentially on the notion that technology held the key to prosperity. The manifestation of this optimism was seen in concrete benefits to segments of North American society: improved clothing, housing, health care, communications and so on. Technology became the focus of public homage.

During the seventies, however, and continuing to the present, there has developed a sense of ambivalence towards technology and its social role. Many of the products of technology are no longer received without question. Vigorous debate has centered on issues as varied as genetic manipulation, nuclear engineering, air pollution, and agribusiness. Such debate places an onus on the population to attempt understanding of complex issues involving technology and its social uses. Understanding the social issues surrounding technology requires that people be technologically literate. In other words, they must examine both the god and his limp.

A Meaning for Literacy

As Emig (1983) suggests, a possible yet incomplete description of literacy

would be "the ability to comprehend, through reading the texts of others, what is new information" (pp. 172-173). Such a perspective ignores the genesis of the text it feels worthy of attention. Staying inside another's text may force one to accept another's meanings. Such intellectual docility may well serve any political or religious majority.

To complete the description, one must include writing. The process of writing demands that the writer move from the external (handwriting and copying) to the extraordinarily internal (authoring; namely, the revision of inner speech). This latter act is the result of synthesis and is original. In practice, writing is probably all these things. Combining reading with writing should, then, be a <u>freeing</u> activity, which removes one from the singularity of others' ideas. Thus literacy gives one power, i.e., one is empowered in one's culture and may be able to move beyond it to create new, more powerful cultural forms if one is literate. It does this by sponsoring thought and imagination about alternatives. The key result of literacy is this empowerment.

A Meaning for Technology

Technology has become a catchword with a confusion of meanings. Kline (1985) attempts to unwrap these meanings. He starts with common usage; namely, that technology is <u>hardware</u>. By hardware he means all non-natural objects manufactured by humans.

He then describes the second most common usage, that of technology as the process of manufacturing the hardware. Kline argues that this descriptor must include <u>all</u> elements necessary to manufacture particular hardware. These would include people, machines, resources, as well as the physical, legal, economic

and political environments. He labels this the sociotechnical system of manufacture.

The third perspective, suggested by Kline, is that of technology as "know-how". "Know-how" is the information, skills, processes and procedures for accomplishing tasks. These three usages, he claims, form the common view of technology.

Kline goes on to argue that these three usages are inadequate. He suggests that a fourth usage is necessary to give purpose to the manufacture of hardware. This fourth concept he labels the sociotechnical system of use. It contains the hardware and people necessary to achieve the purpose of extending human capacities. As an example, says Kline:

> . . . we embody automobiles in a system of roads, gas stations, laws for ownership and operation, rules of the road, etc., and use the combined system (the autos plus all the rest) to extend the human capacity for moving ourselves and our possessions about . . . transport (p. 216).

Thus, without a sociotechnical system of use, the manufacture of hardware has no purpose. Kline elaborates further by stating that "sociotechnical systems of manufacture and sociotechnical systems of use form the physical bases of all human societies past and present" (p. 217). This pattern of purposeful innovation in sociotechnical systems distinguishes humans from other animals. Kline concludes by saying that "few topics are more basic . . . than an understanding of the nature of sociotechnical systems and the pattern in which we humans use them to create the physical bases for our societies past and present" (p. 218).

With Kline's descriptors in mind, consider a model for technology proposed by Pacey (1983). To expand the model past the merely technical, he alters the

term to become technology-practice. The term encompasses the technical knowledge, as well as the organizational and cultural aspects of technology. The technical knowledge appears to be synonymous with Kline's hardware and "know-how".

The organizational aspect is most crucial to the politically minded. It represents public policy and its resultant administration, the activities of engineers, designers and technicians, the needs of unions, as well as users of the technology. This is quite similar to Kline's sociotechnical system of manufacture.

For those interested in ideological issues, Pacey's model offers the cultural apsect of technology-practice. This aspect focusses on the ideology of progress, habits of thinking in technical activity, values of engineers, and ethical codes. This may reflect many of the ideas in Kline's sociotechnical system of use.

The entire model is presented diagrammatically in Figure 1:

(FIGURE 1 FITS HERE)

The combination of these ideas results in a definition for technology-practice which will be used throughout this paper. Technology-practice is "the application of scientific and other knowledge to practical tasks by ordered systems that involve people and organizations, living things and machines" (Pacey, p. 6). A person understanding technology-practice would be well on the road to being technologically literate.

Technological Literacy

If one combines a knowledge of technology practice with the resultant empowerment arising because one is literate, what is one empowered to do?

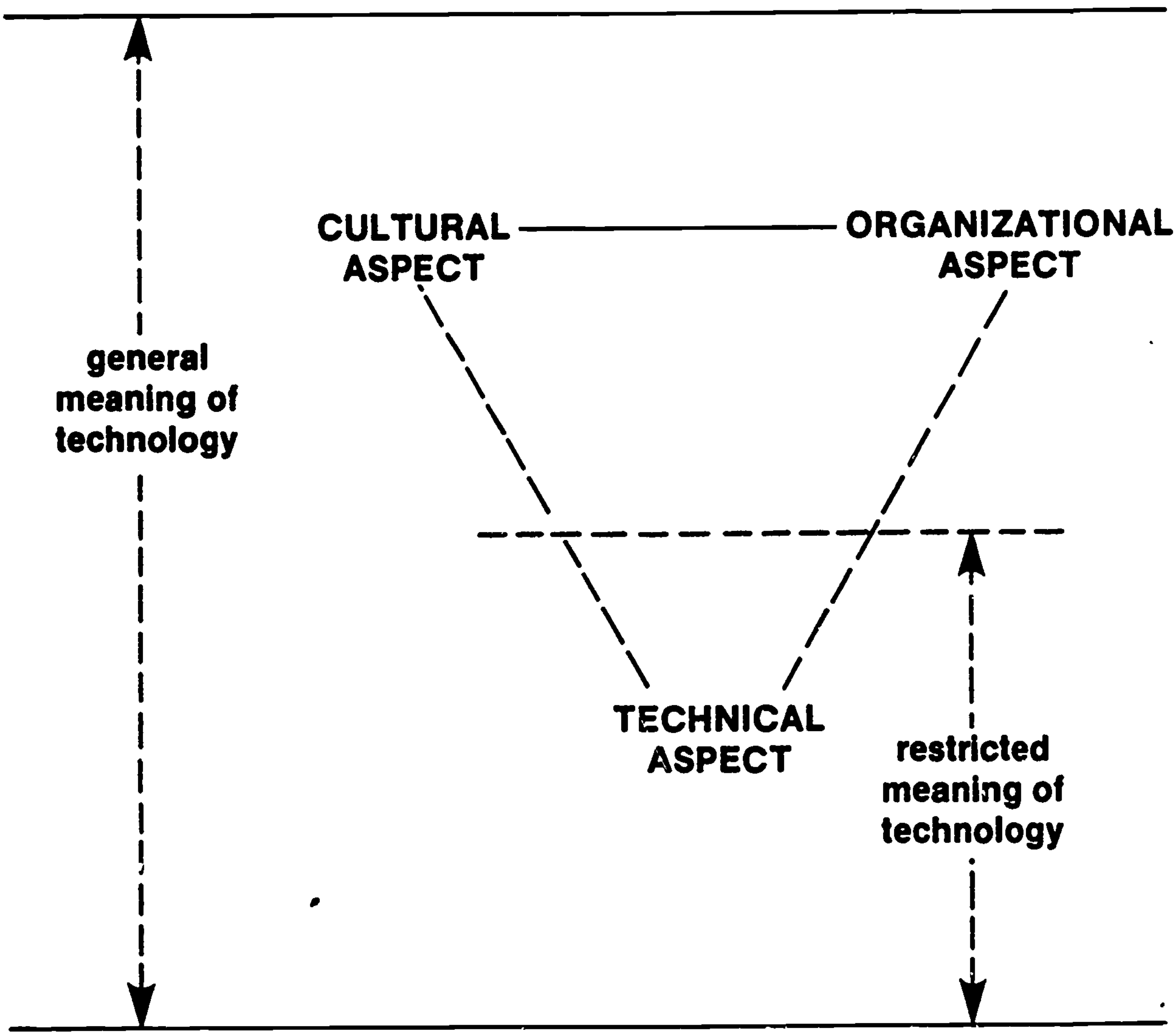


FIGURE 1 Diagrammatic definition of 'technology practice'
From Arnold Pacey, The Culture of Technology, p. 6

One is empowered to imagine alternatives, rather than being confined to others' ideas. The mind can construct "possible worlds inhabited by possible others" (Emig, p. 177). The mind might imagine "alternative social, economic and sexual structures and arrangements . . ." (Emig, p. 177).

A technologically literate person has the power and the freedom to use that power to examine and question:

1. the ideas of progress through technology,
2. appropriate technologies,
3. benefits and costs of technological development,
4. economic models involving technology,
5. the personal decisions involving the consumption of the products of technology, and
6. the decisions made by the managers of technology as they shape the application of the technology.

This list is merely an example of the areas in which a technologically literate person would be empowered. This empowerment would enable such a person to be more critical about technology. Being critical must never be confused with being anti-technology. Rather, being criticl about technology means having the intellectual skills to examine the pros and cons of any technological development, to examine its potential benefits, its potential costs, and to perceive the underlying political and social forces driving the development.

Technology and Science

The traditional view of the relationship between science and technology saw science as the producer of knowledge for its own sake and technology as the consumer of that knowledge in order to produce items to better our lives. In

this hierarchical perspective, science discerned new aspects of the world, and technology put these discoveries to good use.

This view does a great disservice to both science and technology. It should be viewed as either woefully inadequate or totally misrepresentative of the relationship between the two. Examine each of these difficulties in turn.

Contemporary view of science and technology. The model of technology-practice presented earlier is a contemporary view. The three components - technical, organizational, and cultural - interact in a managed way to achieve social purposes. How this management occurs will be discussed in the section on technology and social change; nevertheless, technology is definitely a social institution.

But what of science? The traditional view sees science as the producer of knowledge about the natural world. It has all the philosophical aspects of the discovery model, where individual scientists make discoveries which are eventually published in scientific journals. But science is a human activity, and all human activities have personal and communal aspects as well. Ziman (1984) combines the three dimensions of science - knowledge, person, and community - to create the scheme represented in Figure 2.[1]

(FIGURE 2 FITS HERE)

Thus science is a social institution which will then be connected to various other social institutions such as education, government, business, and

---

[1]It is quite possible to replace each of the terms in Figure 2 with the terms used previously to describe technology-practice: knowledge becomes technical, a blend of person-community becomes organizational, and community becomes cultural.

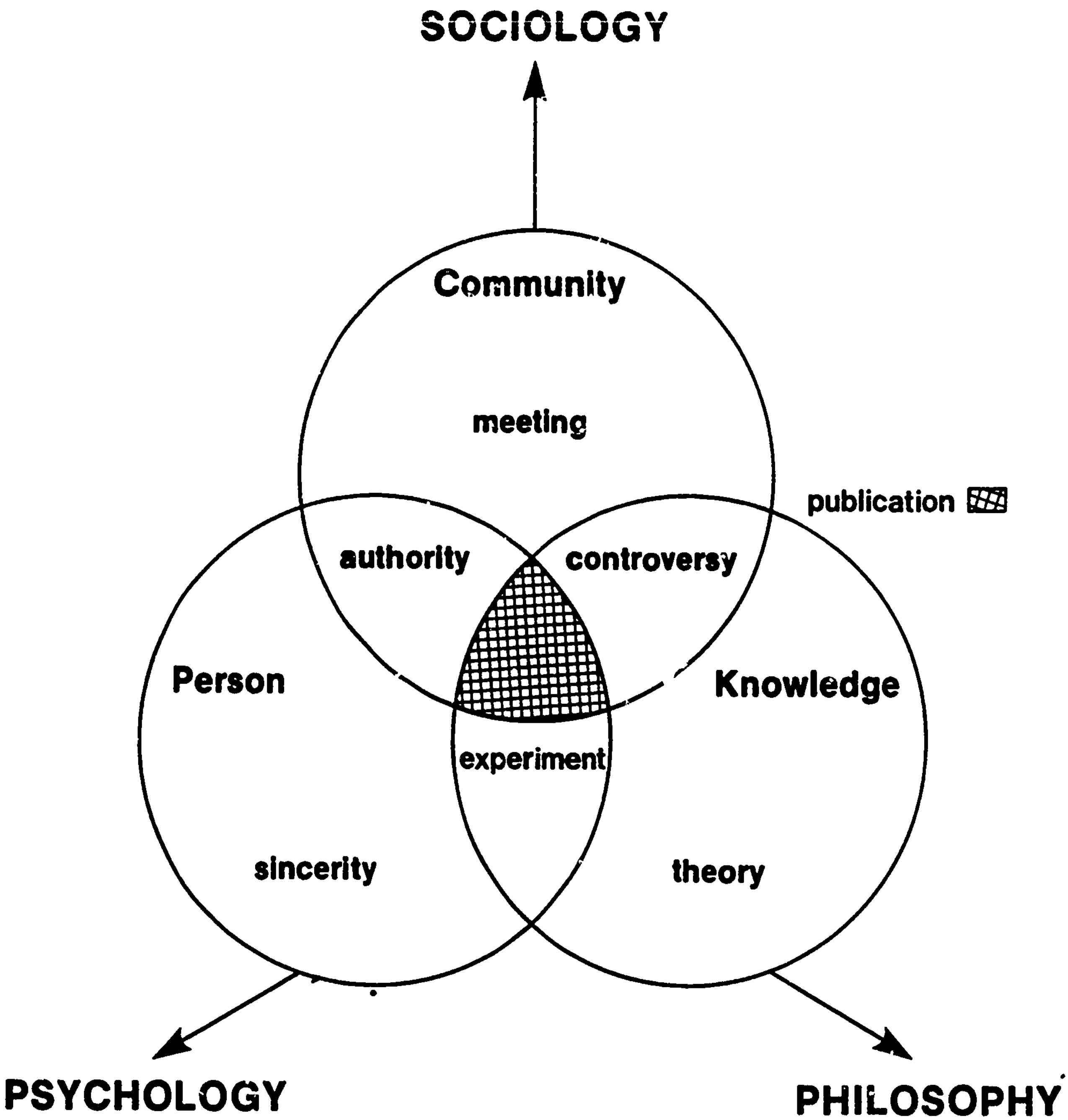


FIGURE 2 Three dimensions of discourse about science
From John Ziman, An Introduction to Science Studies, p. 9

the military. What makes it a unique social institution is that its social role is, as a matter of routine, to extend and modify knowledge. Its role is to change knowledge rather than preserve it.

The relationship between science and technology. The hierarchical notion that technology is applied science is incorrect. Technology can exist without science just as science can exist without technology. However, it appears that the two can make more rapid advances working together. Therefore, a symmetrical model is more appropriate. In this model, technology is not applied science. Nevertheless, recent research (Fleming, 1987) suggests that at least half of the graduating high school students in Canada believe that technology is applied science unless specifically asked to differentiate between the two. Without these specific instructions, in all those cases where such a differentiation would be helpful, students adopted a science-primacy position. An extension of this research to undergraduate science students (Fleming, in press) shows their beliefs to be nearly identical with those of the high school graduates. Thus, it can be seen that students at many levels of education do not know that technology has its own cultural resources. In other words, technologists apply technology just as scientists apply science. A very important implication of this was described in 1976 by Hughes (cited in Barnes & Edge, 1982):

> . . . the state of science sets no necessary constraints on the possibilities of technology, nor, conversely, does a scientific advance automatically indicate a corresponding leap forward in technology. In most cases therefore one must seek to account for a specific innovation as a possible development of the existing technological culture which is realized in response to the pull of external demand, or possibly in response to the needs generated by the interdependence of different aspects of technology upon each other (p. 149).

Thus, science and technology are identifiable cultural groups with their own bodies of knowledge, skills, and competencies.

We can compare the hierarchical and symmetrical views as shown in Table 1:

TABLE 1: The interaction of science and technology

TABLE 1 Two alternative conceptions of Science (S), Technology (T) and the form of their relationship

BASIC MODEL	Hierarchical Technology as Applied Science S | T	Symmetrical S — T
FORM OF COGNITION	S creative/constructive T routine/deductive	S creative/constructive T creative/constructive
PRIMARY BASIS OF COGNITION	S nature T science determinants of cognition	S existing science T existing technology resources for cognition
RESULTS	S discoveries T inventions and applications	S inventions T inventions
MAJOR CONSTRAINTS ON RESULTS	S state of nature T state of science	S no single major constraint T no single major constraint
EVALUATION OF RESULTS	S evaluates discoveries in an unchanging context-independent way. T is evaluated according to its ability to infer the implications of S. Success in T is proper us of S; failure in T is incompetent use of S.	S and T, both being inventive, both involve evaluation in terms of contingent ends. No a priori reason why activity in T should not be evaluated by reference to agents in S, or vice versa.
COGNITIVE FORM OF THE RELATIONSHIP	T deduces the implications of S and gives them physical representation. No cognitive feedback from T to S.	T makes occasional creative use of S. S makes occasional creative use of T. S and T cultural resources.
RESULT OF RELATIONSHIP	Predictable	Unpredictable
PRIMARY MEDIATING AGENCY	Words	People

From Barnes & Edge, Science in Context, p. 151

Even this symmetrical model needs to be unwrapped. We have, for example, science-based technologies (nuclear engineering, radar and the laser) and technology-based sciences (mining and metallurgy). Is it possible to continue to have a clear demarcation between the two? For those new to the field of science and technology studies, the differentiation is an important starting point. But the line between the two is growing increasingly blurred We may feel comfortable saying cosmology is science and automobile manufacturing is technology. For example, what of the relationship between molecular biology and biotechnology? Markle and Robin (1985) claim we have in this case a blend of "the production of knowledge" and the "knowledge of production". It would be safe to say that in this case and other modern equivalents (silicon chips and computers) science generates its respective technologies and technology generates its respective sciences. For the general public, this has resulted in an instrumental view of science in which science is an instrument for achieving social goals. In the research mentioned earlier (Fleming, 1987), high school graduates overwhelmingly supported this instrumental position. They particularly supported the idea that quality of life issues should provide the basis for decisions concerning research funding. Such issues have not been a role for academic, i.e., pure science. For instrumental institutions, however, these issues have almost always been their focus. Instrumental social institutions justify their existence by producing <u>practical</u> knowledge. The production of practical knowledge can usually be accomplished only by generating an intermediate product: generalized (academic) knowledge, which is not immediately practical. Thus science and technology organizations often find themselves simultaneously carrying out these and other knowledge-producing tasks. The range of these tasks is described in the following section.

Research and development. In the eyes of most people, science, as a component of 'science and technology', is an instrument in the hands of society. This instrument can serve a wide range of purposes. Ziman (1984, p. 140) suggests a number, such as:

> Meeting basic human needs, in the form of food, shelter and health
> Making war, or otherwise serving the purposes of the nation-state
> Making profits for competitive industry, through technological innovation
> Improving the quality of life, by eliminating human drudgery and environmental pollution
> Solving social problems, such as overpopulation and economic underdevelopment.

It is now believed that political, military, economic and commercial advances can be made by funding the right kind of research and development (R & D). This funding comes either from the State or large-scale corporations. Only the State can feel confident enough of its permanent existence to take on long-term research projects with large price tags. Funds are channelled to R & D groups through research councils, universities, or government departments. Corporate interests demanding returns on the investment of funds often choose more short-term projects. Because of such differences, the purposes of R & D organizations range along a spectrum of relevance. The divisions along the spectrum include:

i) Basic research: Knowledge produced for its own sake. Academic science in its purest form without any utiliarian purposes.

ii) Strategic research: Knowledge-oriented, but expected to prove its worth in the long run by contributing to practice. No specific practical problem in mind at its inception.

iii) Mission-oriented research: Utilitarian. Specific problem to be resolved.

iv) Technological development: Immediate utility is paramount. Involves design and testing of prototypes. Home for engineers.

The divisions here are not clear cut. Organizations and their members may straddle several divisions, regardless of whether the organization in question is situated in a university or outside it.

The utilitarian perspective evident in much R & D, regardless of its locale, requires that the work and the workers be managed rather than being allowed to evolve according to individual initiative. Research management, with its accompanying bureaucratic hierarchy, is the order of the day. As a result, science workers are collectivized within organizations to focus their energies on specific problems, while, externally, funding from government and corporations forces them to become instruments of deliberate social action.

Technology and Social Change

Technology, in the restricted sense of its definition, causes change in the physical world: A bridge is created to cross a river, a word processor appears on a desk, a building reaches new heights. In the full sense of the

definition, technology's mandate is to change the very society in which it operates. A technologically literate person must understand how technology causes social change; that is, the redistribution of status and power in the society. The process is driven by an elite (or elites), a group or organization which commands the economic and political resources necessary to implement a new technology. Because of its command of these resources, this group, not the creator of the technology, legitimizes the deployment of the technology. The elite will only encourage the testing and large-scale production of a technology if it is seen as useful in maintaining or enhancing its position. A counter-elite may arise in opposition to the position of the elite. If they can muster enough support, they can effectively stop the diffusion of the technology. The movement against the construction of nuclear power plants can be cited as an example of a counter-elite having this effect.

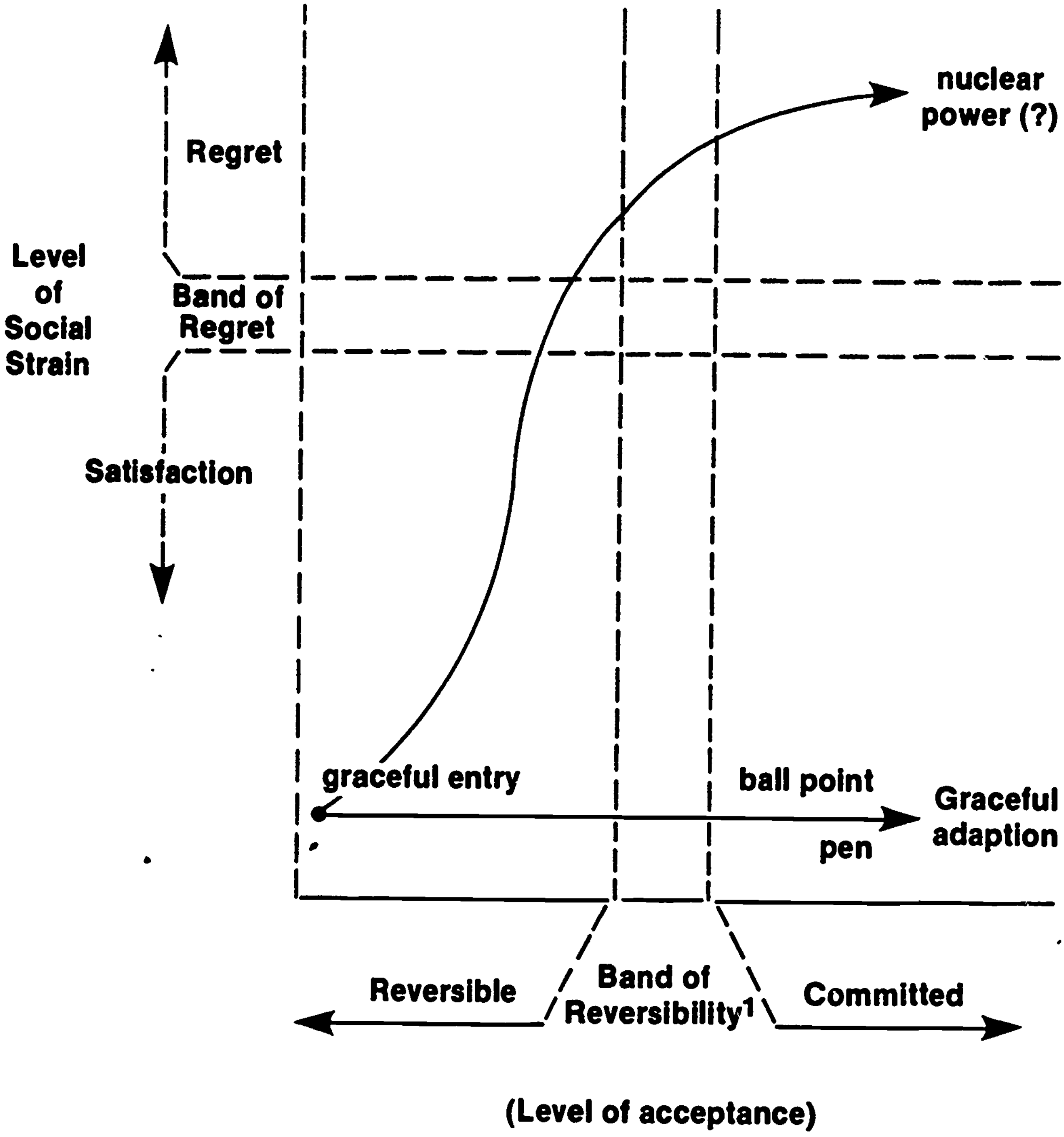
As well, a counter-elite can seize upon a technique which the elite decides not to employ and use it to enhance their own position to such an extent that they become a new elite. The development of barbed wire appears to follow this pattern. As Hayter (1939) states, cattle companies (the elite) were initially opposed to barbed wire and refused to use it. Those who wished to grow crops (the counter-elite) decided to use the new technology. The result, says Hayter, was that

> . . . barbed-wire fences aided in the downfall of the cattle companies as well as the "cow culture" that had developed on the Western Plains during the seventies and eighties. When trail driving disappeared - largely because of the fences - this cultural pattern began to decline, and in its place came, with the influx of the grangers, an economic and social structure that was built, in part at least, on an agricultural system of corn, wheat, and cotton (p. 95).

Let us assume, however, that an elite has the power to increase the production and dissemination of a technology over the objections of a counter-elite. This is the critical phase, for it is now that the spread of the technology may strain the available resources. If it does not, the technology is compatible with the existing system and we get graceful entry into the society. The ball-point pen is a good example of this. If, however, the technology does strain existing resources, the elite alters the socioeconomic system, redistributing power and resources to support the new technology. In other words - social change occurs. As well, when a new technology causes social strain, it becomes politically and socially interesting. It is this strain which prompts technological assessments and legislation to control the technology. Several of these ideas can be represented by Figure 3.

(FIGURE 3 FITS HERE)

A major activity that can arise when a new technology presents itself is the attempt to place this new technology on the chart represented by Figure 3. This attempt usually involves the presentation of positions by various experts. The growth in the use of experts requires the citizen to question the extent to which experts should be given authority, particularly when they advise policy makers who may use this advice to further political ends. Research with Canadian high school graduates (Fleming, 1987) and undergraduates in a science department (Fleming, in press) indicates that the majority favor a technocratic model in which scientists and engineers make the important decisions about social issues



[1]The band of reversibility is that area of activity in which the technology is "going to scale". Once past the band, we feel we cannot live without the technology.

related to technological development. Experts are viewed in a most favorable light.

Habermas (1971) has a number of ideas concerning experts. He calls a society where experts are on tap but not on top, a decisionistic society. Such a society has a political elite at the top. This elite does not need highly specialized skills. Rather, it needs access to the layer just below it, the experts, who pass their expertise up but are expected to restrict the flow of that expertise down to the next layer, the general public. The general public is offered only carefully selected information about technical issues. The resulting ignorance results in a sense of powerlessness and depoliticization. As Barnes (1985) states, the result for the public is that

> Their participation in the political process tends to be restricted to the periods before general elections, when on the basis of restricted and distorted information, filtered by the media, degraded, trivialized and biased by advertising agencies and professional communicators, they choose between competing political elites. Not surprisingly, therefore, many among the main body of the population perceive a sharp disjunction between politics and life generally, and become deeply alienated from their political institutions: occasionally there is active hostility to them, more often complete passive indifference (p. 100).

Thus, opposition to government policies is only possible for those with access to their own experts. In a decisionistic society, then, we have battles between experts acting to legitimate the cases of different sides. Habermas is concerned that during these battles, which are couched almost exclusively in technical language, the expertise offered by those concerned with issues of ethics and human decency is often ignored.

Technological Literacy and Decision Making

It seems that our modern society may be a decisionistic one. If this is so, the public will probably not be consulted over technical questions. An important first step, then, for the technologically literate citizen is to gain a realistic picture of the nature of a decisionistic democracy.

For example, by being a citizen in a technological society, citizens confront complex issues based in technology-practice. Examples abound: experimentation with recombinant DNA, control of nuclear weapons, uranium mining, disposal of industrial wastes, limits to industrial development, and the sources and uses of energy -- especially nuclear power (Patrick & Remy, 1985). To assume that citizens will regularly have the opportunity to confront these issues on the ballot misrepresents the practices of contemporary democracies. The promise of effective collective decision making may turn out to be a political sop. It is important, however, for citizens to examine possible reasons why the issues do not appear on the ballot. Nelkin (1982), for example, suggests that an attentive public causes problems for politicians by raising political dilemmas, particularly in those instances where public attention confronts the economic infrastructure of the country.

Patrick & Remy (1985) suggest that people hold ambivalent beliefs about the social effects of technology. There is, they claim, a "paradoxical blend of dread and anticipation, of fear and hope" (p. 13). Citizens may choose, of course, to emphasize their fears instead of their hopes in science and technology when they participate either as voters in referenda and initiatives, as members of political interest groups, or as public officials. This emphasis seems to be misguided. It seems more appropriate to examine, as a starting point, why fears arise over technological developments.

One major reason centers on issues of uncertainty about the consequences of various courses of action. In simple terms, citizens worry about risk. Part of this worry is due to the incorrect premise that experts have all the information and hence all knowledge of all possible outcomes (visceral experiences to the contrary). This arises from a misunderstanding of the nature of science, the nature of technology, and the nature of expertise!

Another component of the worry is a lack of understanding of the concept of risk. This is a crucial point. Research (Kahneman, Slovic, and Tversky, 1982; Nisbett and Ross, 1980) indicates that most people perform very poorly when attempting to make decisions involving uncertainty. At the collective level, risk appears to be central to an appreciation of the perceived necessity to consult experts. Expertise often focuses on the acceptability of risk. Discussions with experts on risk issues must of necessity deal with health, occupational safety, job security, profit, and so on. Different values will emerge -- protecting worker health versus protecting production and jobs. The compromises made in an attempt to accommodate these value positions are worthy of study. A first step is to help future citizens assess the value-laden relationship between so-called factual information and the decision-making process.

A depoliticized electorate has little use for personal decision-making skills about technology if all technical decisions are made by the "on-tap" experts. Nevertheless, a first step would be to understand who makes the decisions, with a particular emphasis on possible biases. The next step might be to examine the proposed technical bases for these decisions. Technical arguments are presented in a logical, rational form. They are designed to defuse controversy. Controversy arises when there isn't consensus on an issue;

if there is no consensus, a smattering of technical knowledge won't help a citizen decide whose expert is right. More important that the person understand the value claims implicit in the conflicting positions and realize that a struggle over the acceptability of value claims is an inherent part of science and technology.

Technological Literacy and the Computer

There can be little doubt that, in the minds of many educators, the term "technological literacy" is synonymous with "computer literacy". As Dyrenfurth (1984) warns, however, ". . . the advocates of computer literacy must learn their place in the rightful order of things. Computers are but one part of the technological species. Technology is not a part of computing, rather computing is an aspect of technology. Given this relationship, the concept of technological literacy subsumes computer literacy" (pp. 10-11). If, as has been suggested (Sullivan, 1983), the micro computer is the personification of progress, schools must be seen as marching to the tune of the same drummer. As a result, almost overnight, computers have appeared in schools. Knowing what to do with them has been a different matter. To help resolve this concern, and to minimize the idiosyncratic approaches of well-meaning individuals, workshops and curriculum guides focussing on "computer literacy" have been created.

The Department of Education's 1984 curriculum guide for Division III, titled "Computer Literacy" is an example. The course content appears to reflect the model for technological literacy presented earlier. Technical skills such as keyboarding and programming skills in BASIC (the narrow view of technology in Pacey's model) are enhanced with social/historical understandings such as "contrasting computers and human minds" and "social control of

technological change". Were teachers to use the suggested scope and sequence (p. 18), the curriculum would reflect a blend of the technical, cultural, and organizational, and might aid in the development of a computer literate individual.

The 1984 Curriculum Guide for Division IV, presents an interesting view of "computer literacy." First, consider the computer science courses. These courses are "designed especially for those students wishing to learn in some depth about the use of computers for problem solving" (p. 47). It is expected that fewer students will opt for such courses. Programming courses such as these fit the "technical" description of technology discussed earlier. This narrow perspective is comparable to many of the traditional vocational programs currently offered. Programming skills would be comparable to using the lathe. Computer literacy is not the goal in Division IV. This was to have been developed in Division III.

The Division IV Computer Applications courses are another matter. It might be helpful to view the underlying assumptions of these courses from two perspectives. On the one hand, there is the liberal education idea of the computer as a tool for personal use and growth. Smith (1983) refers to this as the drive for social competence. On the other hand, there is the computer (and school) as training ground for employment.

The computer as a tool for personal use and social competence offers a road to empowerment, the key concept in literacy. A number of interesting "basics" come to mind: word processing, accessing data bases, and the creation of electronic filing systems.

The powerful word processing software currently available for microcomputers allows almost all students to create elegant text. The writing

process is enhanced because shaping and refining ideas in print becomes practical and economical. Keyboard skills are helpful here, for they prevent the student from being held back due to lack of a technical skill. The insistence on keyboard training may be a short-lived phenomenon, however, as voicewriter technology becomes more available.

Being able to access data bases simply opens the door to vast amounts of information. Getting people to walk through the door is another matter! Nevertheless, awareness of the availability of these data coupled with the skills necessary to access them are the first steps towards having students use the data.

Molnar (1986) states that the critical question is not how much information we can generate but rather what information is of most worth and for what purposes. He believes that information and information technology pose two types of curriculum and instruction problems. The first type of problem deals with "the role of information, information technology, and the use of information in society" (p. 65). He refers to this as the sociology of information. Curricular topics in this area would include

> . . . the role of government and private institutions in creating, processing, and disseminating information; the political and social implications of alternative information policies; and the merits of different information policies. The sociology of information is an important area to study because the information policy issues involve scientific, social welfare, and foreign policy matters as well as the fundamental relationship of the government to the governed. For example, the question of whether a given policy encourages the concentration of information in the hands of a few or makes information widely available is of primary importance to democratic governance (p. 65).

The goal of this curricular initiative is to graduate students "reasonably familiar with the public policy issues posed by information and information technologies" (p. 65).

This graduation requirement is needed to counter the technological imperative, to avoid naive faith in the technical solution to every problem, and to make sure that the social cost of technological change is fairly spread in the community (Smith, 1983, p. 10). Information technology can be used to support totally different sets of social goals, to manipulate or to liberate, for "the control of disorder" or "the management of diversity" (Mowshowitz, 1976).

The second type of problem Molnar labels the technology of information. The problem appears to be the focus of curriculum guides such as Computer Science and, to the extent that it promotes technical skills over understanding, Computer Applications.

When one turns one's attention to the relationship between computer applications and employment, other issues arise. Word processing is now taught as an adjunct to business, not as a tool for empowerment through writing. Spreadsheets and data base management are taught because these are skills required by businesses in the high tech age. The inclusion of these skills is representative of increased collaboration between schools and employers. This collaborative position is summarized in Giroux and Aronowitz's (1985) statement:

> If schools have been training institutions masked as purveyors of the western intellectual tradition, better to take off the mask and get down to the business of . . . education - namely, business (p. 186).

One must explore what demands these messages place on schools. The central message appears to be that schools must help the country weather technological change. Schools do this in two ways, argues Smith (1983). First, they produce a work force with the qualities and skills needed to make a country economically competitive in a world of high technology. Secondly, they help people deal with the idea of a drastically different future brought about by this high technology. These can be labelled as "economic survival" and "individual well-being".

Many argue that economic survival is a necessary condition for individual well-being. (Whether it is a sufficient condition will be left to another article!). Schools are encouraged to foster in students a positive attitude towards things technical. This is sometimes done under the guise of life skills and work experience programs. The ultimate goal would be to increase the number of bright students choosing careers in industry. This is often referred to as the capability argument, for it proposes that a central purpose of schooling is to render students capable of living meaningfully in an industrial society.

As well, one is confronted with the vocational argument, which demands workers with the right skills for high technology. The central concern here is with making those skills learned in school directly transferable to the workplace.

What is the projected impact of computer technology on the workplace? It appears that most new jobs created by advanced teachnologies will be less skilled, requiring little specialized knowledge, (U.S. Bureau of Labor, 1983). This deskilling is the result of succeeding generations of technologies reducing the quality and duration of the prerequisites needed to perform in the

service industries. As well, this deskilling arises as a result of transferring skills to machines. Schools, then, are wasting their time preparing masses of technically skilled labor. It appears that the information society will offer plenty of opportunity for janitors, hospital orderlies, and fast food servers. As a result, future workers must be educated to examine the impact of technology on the workplace, particularly with regards to health, safety, and changing occupational roles. Hence, the purely technical aspects of computing such as programming should be overshadowed by the emphasis on cultural and organizational changes produced by the technology. For example, students should study the effects of transforming industrial societies into service economies as material production shifts to developing countries where labor costs are low and tax breaks lucrative. The major transnational corporations, utilizing information technologies, have the capability to manoeuvre in such a business environment. Regardless of this, schools will continually exist in a state of tension as they try to balance the often conflicting demands for economic survival and individual well-being, capability and a critical spirit, and social competence and moral autonomy.

Technological Literacy and Curricular Frameworks

It should be obvious that being technologically literate is not the same as being technically trained. The latter, traditionally the role of industrial arts and vocational education, is the narrow perspective presented in Pacey's model. A contemporary framework for this narrow perspective has evolved around the idea of design and technology. This curriculum idea asks that students come to grips with the problems of living in, and exerting their influence upon, the constructed world. This is a practical curriculum stressing the

students' technological capabilities. Even so, the curriculum goes beyond the merely mechanical to demand that students spend some time examining ethical, social, and economic ramifications of specific designs. Examples of the abilities students are expected to demonstrate are shown in Appendix A.

Curriculum frameworks which encompass all aspects of the model of technology have also been prepared. Bugliarello (1985) suggests a focus called socio-technology in which attention is directed to the interaction between the design of technological systems and the analysis of social systems and process. Socio-technology, then, appears to be very congruent with Pacey's technology-practice and Kline's sociotechnical system of use. Bugliarello goes on:

> As a discipline, socio-technology has two distinct objectives. The first is to understand the interactions between a technological system and the social environment both inside and outside of the system. Since a technological system is but a special kind of social system, the scope of socio-technology extends to the interactions among social systems in general, or between social systems and their environment.
>
> The second objective of the discipline of socio-technology is to shape the interactions among social systems to respond to specific goals. Such a definition of socio-technology as a discipline dealing with social and technological systems' interactions has several useful characteristics:
>
> 1. It is general. It encompasses, for instance, several of the definitions of the subject.
>
> 2. It indicates, by its very name, the pivotal role that technological concepts have in the study of the interaction among social systems.
>
> 3. It indicates, again by its very name, the multidisciplinary nature of socio-technology.
>
> 4. It accommodates both analytic and operational (technological) goals.

5. It leaves open the complex and value laden question of the possibility and desirability of an integration (versus interaction) of technology and other social systems.

To achieve its objectives, socio-technology needs to synthesize the methodologies and goals of a large number of existing disciplines having bearing on the interactions among technological and social systems. These disciplines can be grouped in several categories:

1. Background disciplines to understand the behavior of social systems, such as sociology, psychology, economics or history.

2. Background analytic disciplines to develop physico-mathematical and logical models of systems and their constituents, such as systems science, cybernetics, operations research, management science or issue analysis, as well as some aspects of the philosophy of technology.

3. Forecasting disciplines or activities, ranging from technological forecasting to the less scientific "future" studies.

4. Activities focusing on impacts of one system on another, such as environmental impact analysis or social impact analysis, and, more generally, technology assessment, as well as some other kinds of assessments.

5. Disciplines or activities focusing on the design of systems interactions, such as science policy, systems planning and design, organizational design, finance and macroengineering.

6. Disciplines or activities focusing on the operational problems of systems interfaces -- such as decision theory, operational management or maintenance.

7. Disciplines or activities focussing on the design, construction and operation of technologiccal systems, such as engineering.

Bybee (1985, p. 85) has suggested another framework for science-technology-society education, involving goals, themes, areas of emphasis and

activities. It appears to embody a number of the suggestions made by Bugliare lo.

A Conceptual Framework for Scientific and Technological Literacy

Goals	Acquisition of knowledge	Development of learning skills	Development of values and ideas
Themes	Concepts of science and technology	Process of scientific and technological inquiry	Interaction of science, technology, and society
Areas of Emphasis and Activities	Personal matters	Information gathering	Local issues
	Civic concerns	Problem solving	Public policies
	Cultural perspectives	Decision making	Global problems

If one focusses on technological literacy in Bybee's framework, a three-dimensional grid can be prepared. This is presented in Figure 4. The grid emphasizes the interrelationships among the three major items. To superimpose both grade levels and core subjects on this grid would require multidimensional reasoning. Nevertheless, it is possible to present a sample grid for each of Division I-IV, with curricular emphases shaded. These are presented in Figures 5 to 8. The three dimensions labelled on the grid suggest that curricula should be designed such that they move students from the simple to the complex: from the personal to the cultural, from information gathering to decision making, from a local to a global perspective. The shaded areas for each division represent the area to be emphasized by the curricula. They do not preclude an expansion or enrichment as the curriculum developer and teacher see fit. They do represent the minimum requirements for that division.

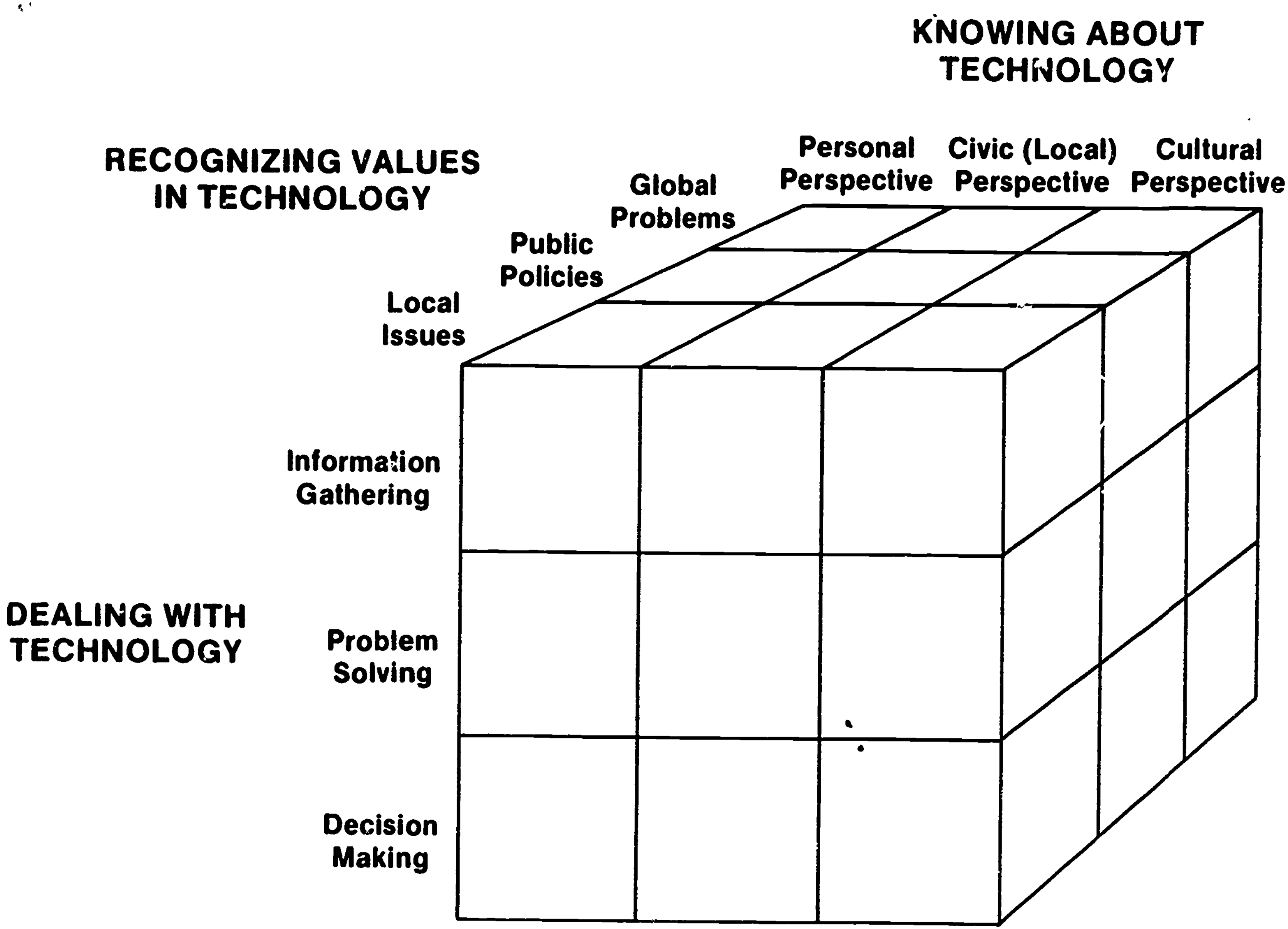
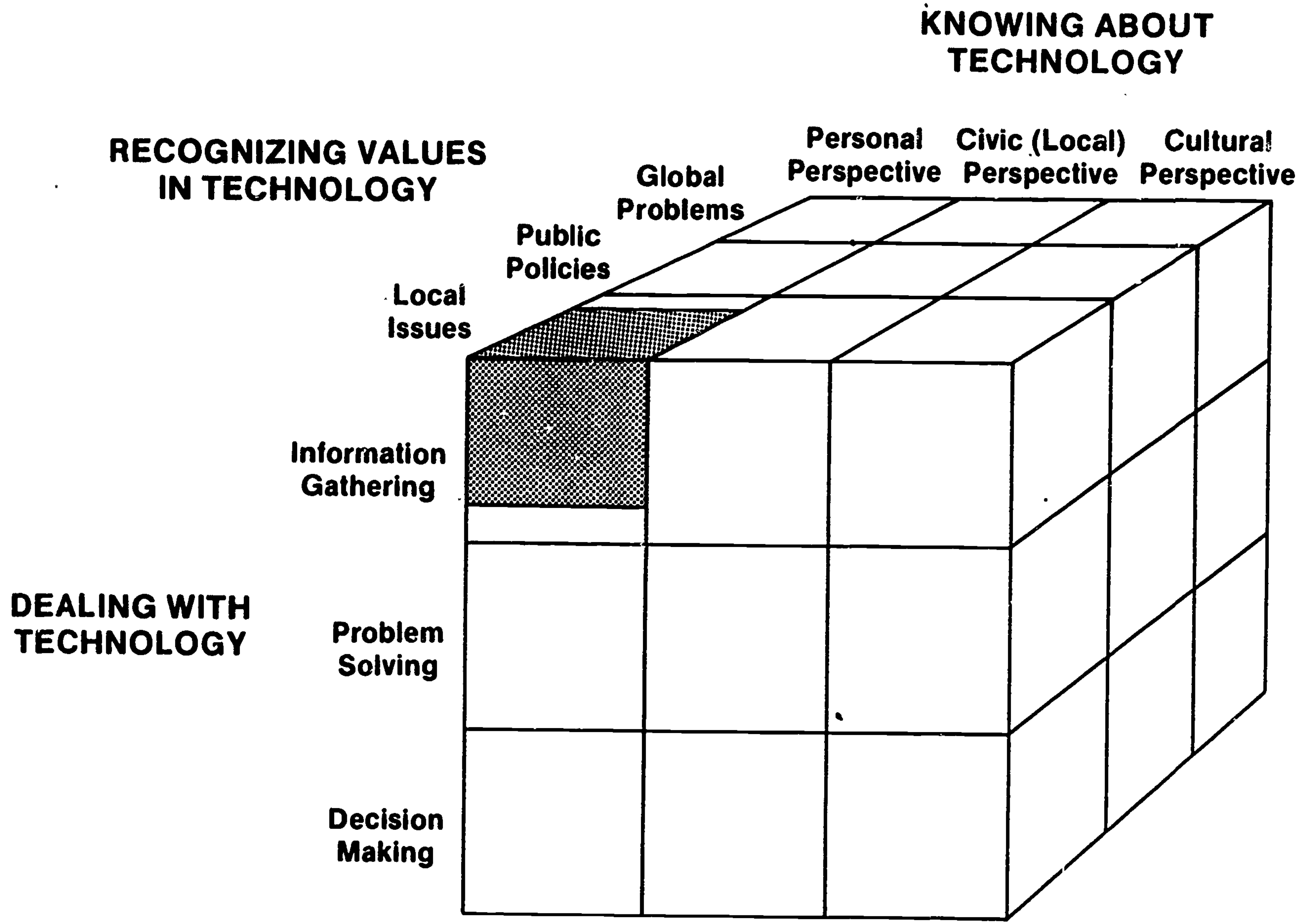


FIGURE 4 A CURRICULAR GRID FOR TECHNOLOGICAL LITERACY



30

FIGURE 5 A CURRICULAR GRID FOR TECHNOLOGICAL LITERACY: K-3 emphasis

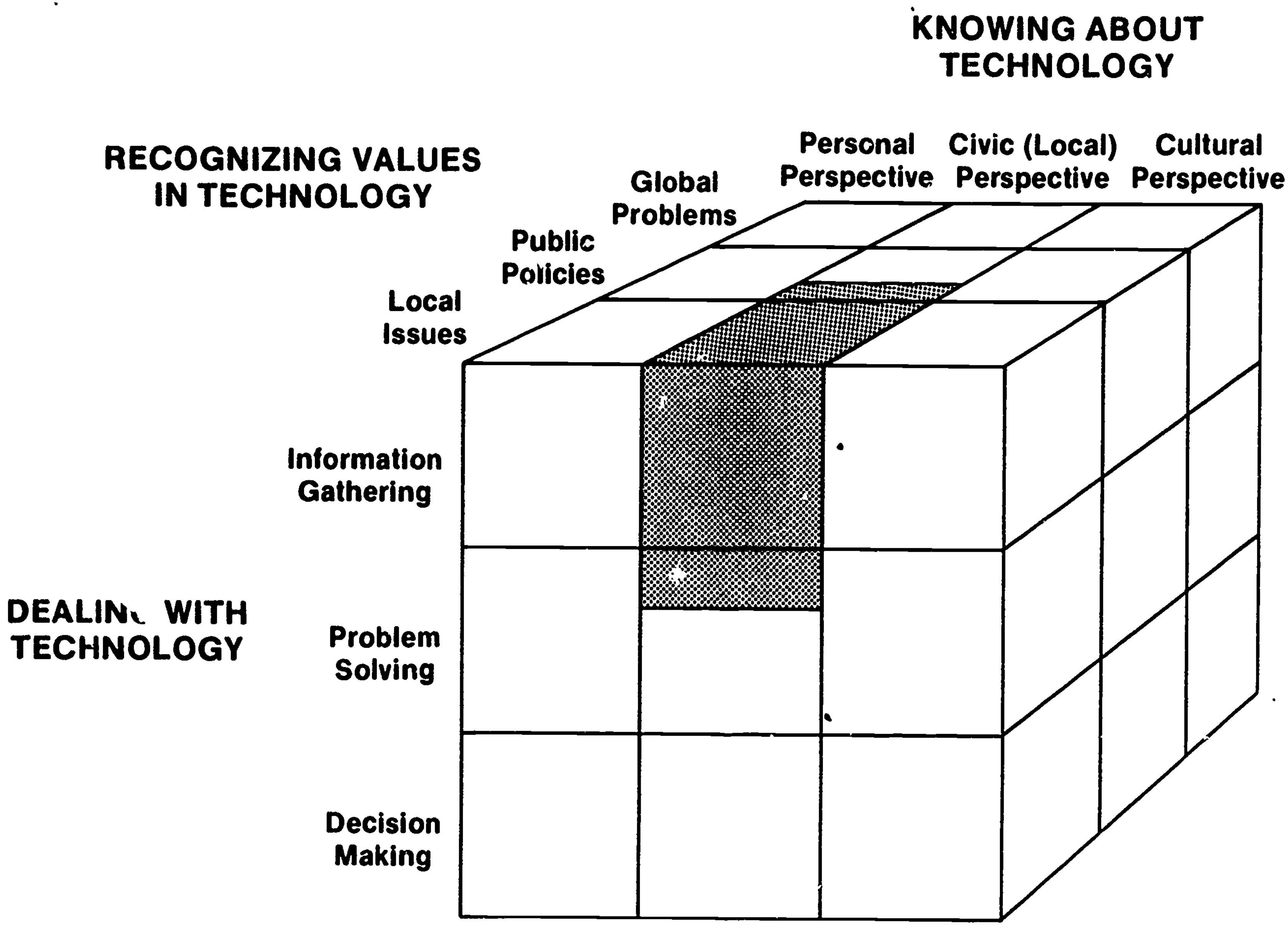


FIGURE 6

A CURRICULAR GRID
FOR
TECHNOLOGICAL LITERACY
Div. II (4-6) emphasis

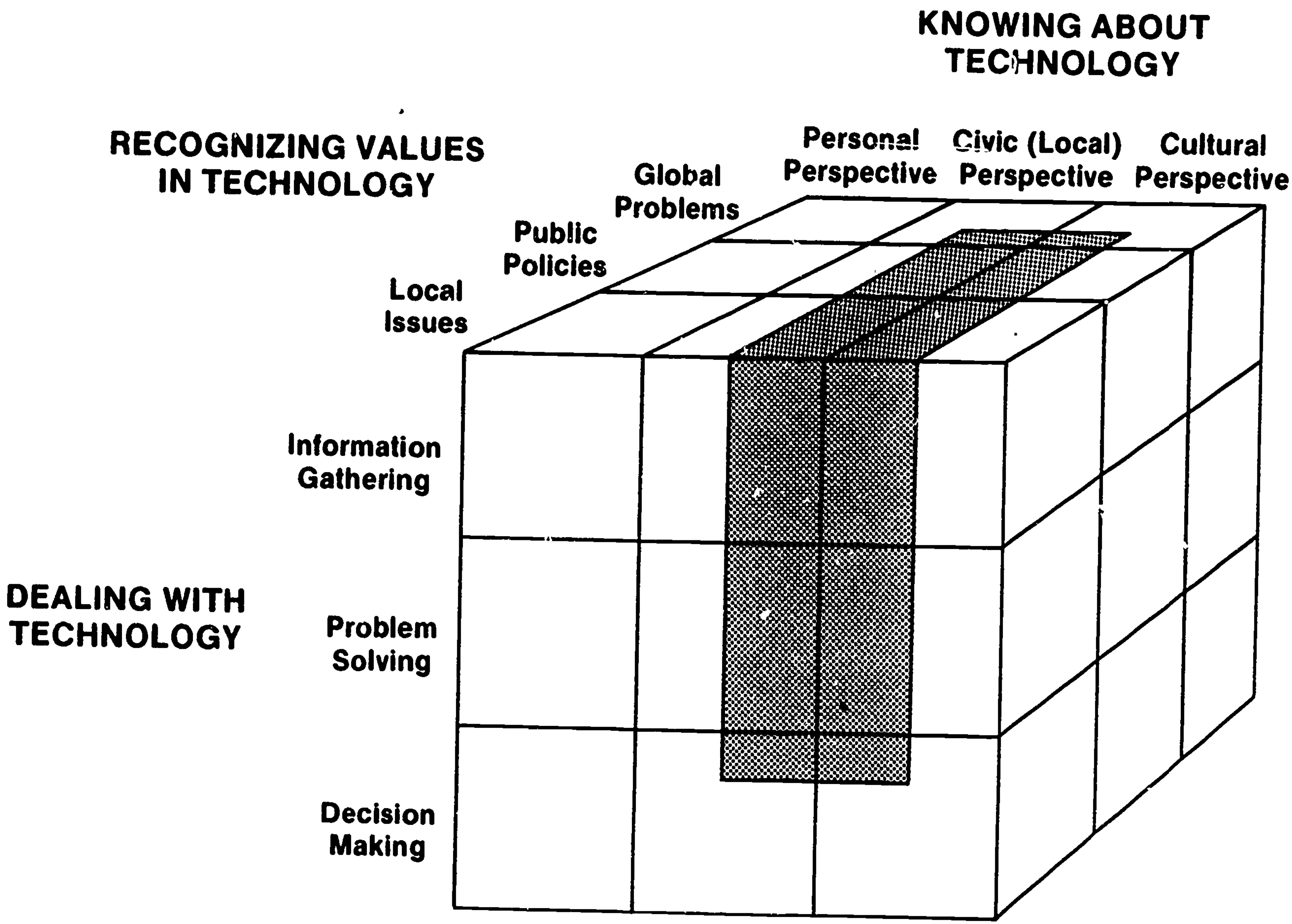


FIGURE 7 A CURRICULAR GRID FOR TECHNOLOGICAL LITERACY Div. III (7-9) emphasis

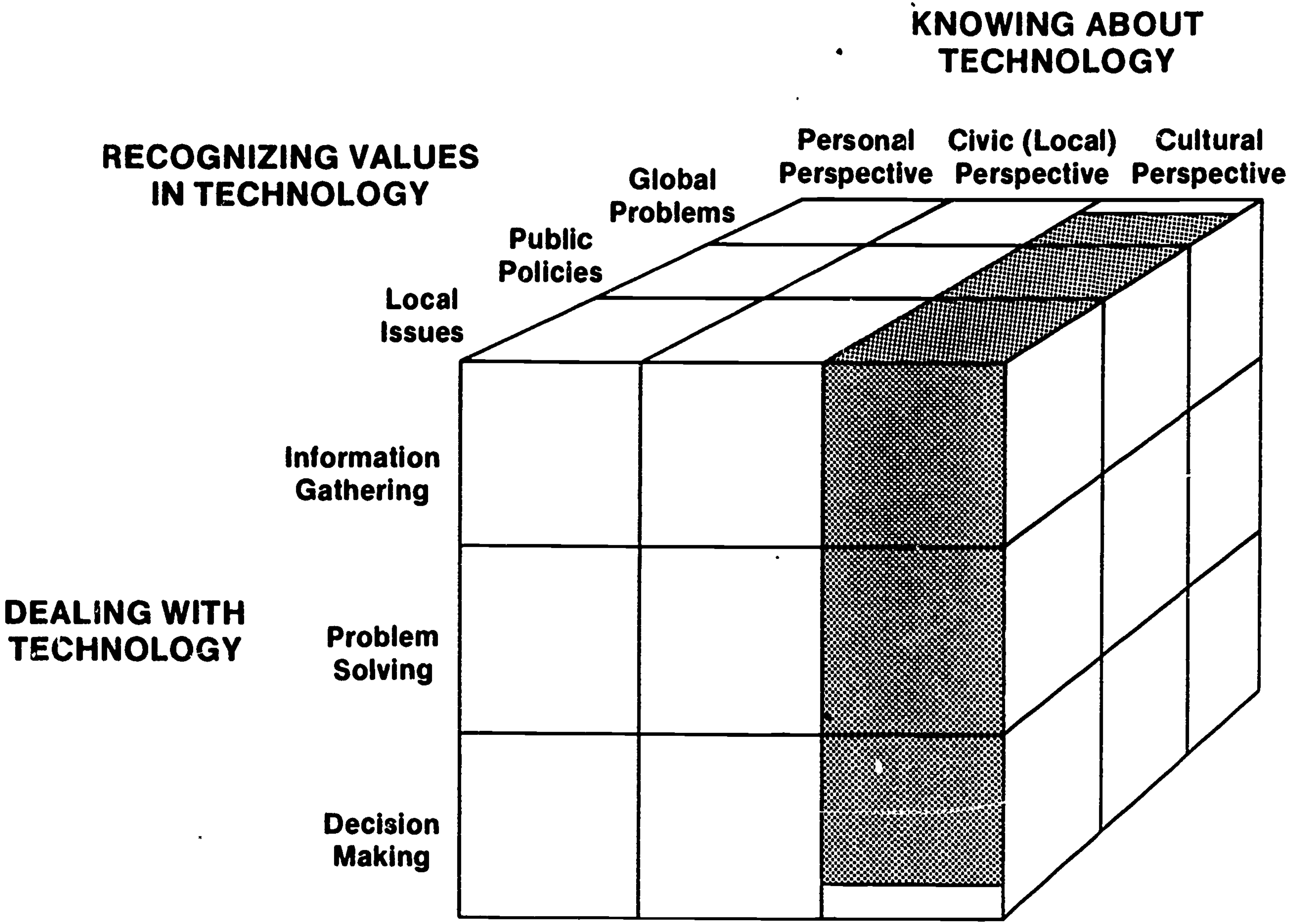


FIGURE 8 A CURRICULAR GRID FOR TECHNOLOGICAL LITERACY Div. IV (10-12) emphasis

CONCLUSIONS AND RECOMMENDATIONS

I. General Conclusions and Recommendations

A. Curriculum developers must do everything in their power to avoid becoming trapped in a narrow definition of literacy. Reading and writing are woefully inadequate definitions. Of course, they do serve a particularly instrumental view of education, especially a so-called skill based model, in which the ability to translate the written page and possibly duplicate it with some instrument dominates. There is, at one level, nothing wrong with the emphasis on these "basics". Curriculum developers should examine the arguments presented in Trevor Gambell's paper Language Across the Curriculum dealing with these basics.

The position advocated here is that of literacy as a tool for empowerment. A literate person is empowered to consider alternatives and is hence free of the singularity of others' thoughts. Such an individual is capable of critically considering alternative cultural arrangements, be they social, sexual, economic, or political. To understand how a person can perform such critical thought, the reader is referred to Sandra Klenz's paper Critical and Creative Thinking.

RECOMMENDATION: Curriculum developers must offer students the opportunity to examine alternative versions of contemporary culture. This examination must demand of these students that they read, write, and speak about these cultural alternatives.

B. There can be little doubt that there are many misunderstandings about the meaning of technology. First, technology is not just a study of tools and

their uses. This is a very narrow definition more suited to primitive versions of Industrial Arts. This is not to say that Industrial Arts is an inappropriate task for the schools. Rather, it suggests that the technical skills acquired during Industrial Arts will never be sufficient to make a student technologically literate. Even the contemporary design curricula, which include issues such as the ethics of design, are narrow versions of what is envisioned in this paper.

Secondly, technology is not applied science. This is a very popular perception; namely, that science discovers and technology applies these discoveries to improve the quality of one's life. It may be possible to trace this popular misconception to the misguided attempts by many scientists to justify the expenditure of public funds on the basis of future benefits in the form of new refrigerators, microwave ovens, and the like. Most politicians were quick to capitalize on this idea, particularly as the spin-off benefits of this "applied science" led to economic prosperity and the possibility of re-election. The applied science perspective presents technology in a far too passive light.

A more appropriate view of technology is that of sociotechnology. In this view, technology is understood as a social process in which the knowledge created by science and the knowledge created by technology are "put at the disposal of people who in general are not themselves competent in these knowledge bases and who wield them on behalf of ends reflecting a parochial interpretation of prevailing personal, institutional, and social values" (Goldman, p. 121). In other words, managers decide what benefits may accrue from the use of these knowledge bases. It is these decisions that determine what will be the ultimate products of technology, not the scientific and

technical knowledge. To understand technology, then, requires that one understand the social forces brought to bear on those who make the decisions.

RECOMMENDATION: Technology must be presented as socio-technology; that is, a social process that can exist independently of science and whose direction is shaped by the needs of managers who are not trained in the technical aspects of technology.

C. Part of the difficulty presented by Recommendation B is that it leaves the reader undecided about the nature of the relationship between science and technology. The simplistic notion that science discovers and technology appl... has been described in conclusion B. What, then, is the nature of the relationship between the two? The public perspective seems to be one in which science serves a ultilitarian purpose -- that is, science exists as an instrument for achieving social goals. This allows for a blurring of any differences between science and technology, resulting in a combined enterprise called "technoscience'. A contemporary term for technoscience may be "research and development" (R&D). To most, R&D implies mission-oriented research whose ultimate goal is the creation of marketable products. This is the description offered by political parties and entrepreneurs. This description overlooks the necessity for basic and strategic research, whose function is to provide a knowledge base for potential use. Even a ultilitarian model of science must allow for these two processes. Science and technology, then, are linked by the necessity for pure research as well as the necessity for business success. There is a dialectic between knowledge and production. This dialectic is the essential tension between science and technology.

RECOMMENDATION: The dynamic tension between the production of knowledge and the knowledge of production must be an integral part of the education of the technologically literate person. The concept of utilitarian science must be tempered with an understanding of the need for pure science. Science and technology should be presented as having a symbiotic relationship.

D. The omnipresence of technology in our society has led many to suggest that technology is the dominant agent for change in the society. The problem with asserting that technology causes all social change is that this position seems to deny that society has any impact on the direction of technological development. There is no doubt that technology's mandate is to change the society in which it operates. A technologically literate citizen must understand the nature of the relationship between technology and social change. To assume that the change flows in one direction, i.e., technology causes social change, is to surrender one's self to the inevitability of technological development and its concomitant social changes. The most important concept for the curriculum developer to consider here is that of the reciprocity between technology and society. The curriculum developer must create curricula that allow students to examine their options as citizens in the face of technological development. They must present students with the chance to examine how their actions have an impact on the course of technological development. As well, students must be encouraged by the curricular materials to examine the arguments presented by the developers of technology in defence of their position.

RECOMMENDATION: Curriculum developers must present the relationship between technology and society as a reciprocal one; that is, technology has an impact on society and society has an impact on technology, both of which result in social change.

E. There appears to be an abdication of any feelings of potential worth when many people are asked to voice an opinion concerning technological issues. This feeling of impotence makes itself manifest through the desire to rely on expert opinion in matters technological. Issues such as the decision to build a nuclear power plant are felt to be best left to well-trained experts. An understanding of the nature of expertise is sorely needed. The value positions taken by experts representing various interest groups are excellent sources for such studies.

RECOMMENDATION: Any curriculum dealing with technological issues must confront the issue of experts and expert decisions. Expertise as a social phenomenon should be a subject of study.

F. For educators, the computer seems to represent the tip of a technological iceberg. The sin of being "computer illiterate" may be rewarded by the scorn of one's colleagues and the feelings of incompetence engendered by one's own ineptitude. "If this is technology, I'll have none of it" is a common response. Competence with the technology may result in higher esteem amongst selected colleagues manifested by increased demands to consult with those less able. Many of these latter tasks revolve around computer programming, particularly among those thrust into this rather (to them) arcane world.

I contend that this fixation with computer technologies has resulted in a massive misplacement of teacher effort. One must ask serious questions about the role of microcomputers in teaching. As this question is asked, one must also be aware that the microcomputer, in the minds of many, is the embodiment of technology. Programming the microcomputer has become synonymous with being technologically literate. This is a woefully inadequate description of technological literacy. At best, it is representative of the narrow definition of technology described in the body of the paper. Any person equating computer literacy with technological literacy is making a grievous error.

If programming is not the curricular route to take, what is the curriculum designer to do? Referring to the model for technology presented earlier, computer technology must be presented in its social context. To be computer literate, as a subset of being technolocally literate, means primarily that students can examine and understand the nature of the relationship between information and its origins. Such an understanding does not require courses in programming; rather, it requires the ability to analyze information with respect to its genesis and, given the earlier definition of literacy, to consider the alternatives to the presented position.

Let us now consider the concern about "keyboarding skills". It appears that this skill is highly touted as a necessary condition for activities with a microcomputer. It would be a necessary condition if evidence was provided to support the thesis that lack of these skills would prevent students from using the device. Keyboarding seems to be a short term skill, destined to be rendered obsolescent as soon as more sophisticated software removes any need to be a speedy typist. On the other hand, if word processing software allows students to write more efficiently, many schools will want students to use this

software at earlier ages. It is quite feasible that elementary school students will be required to use a keyboard to produce written documents of high quality. This can only be viewed as short-term trend which will be quickly altered by advanced software packages.

In summary, then, computer technology must be seen as a subset of technology in general. All the criteria for discussing technology must be applied to the microcomputer. Programming issues, then, fall under the category of the narrow definition of technology. They may be intrinsically interesting, but they are a far cry from the more all-encompassing definition of technology offered earlier.

The current curricular offerings of computer applications and computer programming are highly suspect. Their avowed purpose is to allow teachers to teach a technical skill, which, they claim, is highly necessary in today's increasingly technological world. In the light of the arguments presented in the paper, this argument is misleading. Hence, programming and applications courses will do nothing to make students technologically literate, nor will they make students more employable.

RECOMMENDATIONS:

1) Computers in classrooms must be presented as tools we use to enhance the activities natural to classrooms. Thus electronic mail, word processing, simulations, and accessing large databases would be appropriate uses for the computer. Many of these uses are not subject area specific.

2) The major focus of computer studies should be on building an understanding of the relationship between information and the social forces, cultural beliefs, and economic realities behind information.

3) Building courses around keyboarding should be avoided. If all students have access to computers to perform classroom tasks, a single course in the rudiments of typing should be given to all students. This should be done as early in their education as they are physiologically able.

4) If "keyboarding" becomes the basis for a course, its viability must be examined yearly.

G. A traditional model of a democratic society suggests to students that they have a form of control over those whose decisions affect the course of the country, province, or town. In the case of technology, where economic interests dominate, there quite naturally arises a sense of loss of control over the course of technological development. With technological development often intimately tied to government policy, citizens may feel that whatever they have to say about technology will likely have little impact. This sense of impotence in a democratic society must be addressed. It appears that social studies may be the best equipped to do this.

RECOMMENDATION: A useful picture of the nature of contemporary democracy and the role of the citizen within that democracy must be presented.

H. Many proposed technological actions are viewed with alarm. The site for a nuclear power plant or a petrochemical complex may prompt intense debate among citizens. One major reason for these debates is that most people do not have any understanding about the consequences of the proposed technological action. People worry about the risks associated with the action. Expert opinion, much

of it contradictory, will do little if anything to allay public concerns, for it appears that the public has a visceral understanding of the value-laden positions of experts. (See conclusion E)

RECOMMENDATION: The concept of risk must be included in appropriate curricula. At the moment, it appears that this could be done in mathematics and social studies primarily. I do not recommend that this bog down in the labyrinth of sophisticated statistical procedures. I see math offering an introduction to probabilities and social studies teaching students how to analyze value positions. These two positions may come together and be used simultaneously in general science curricula.

I. If, as we are often told, we live in an information age, the issue for educators has become one of teaching students how to live effectively in an information age. The analysis of data from this perspective is of paramount importance.

RECOMMENDATION: Students must be given the opportunity to determine what information is of most worth based on the intended uses for the information.

J. The promise of a golden age through technology cannot be tolerated in any curricular proposals. Technological innovations must be presented in a humanitarian risk-benefit framework. Promising students that technological innovation, especially those labelled "high tech", will necessarily lead to a multitude of golden employment opportunities for all is a dangerous and immoral practice. The labor data simply do not support these projections. Curriculum

developers must be well informed as to what the major job arena may be. If, as has been suggested, it will be the service sector, the major technological impact on this sector must be presented. It seems the major impast may be in the area of worker health and occupational safety. Hence, the core subject "Health" must deal with the issue of occupational safety as related to technological development.

RECOMMENDATIONS:

1) Technology must not be presented as the solution to an individual's economic ills.

2) Worker health and occupational safety must be one focus of the study of the relationship between technology and employment.

II. Subject Area Recommendations

Language Arts

Language Arts must help students understand why human society reads, writes and speaks. Students must be encouraged to examine the concept of an "information age," with a particular emphasis on the critical analysis of the information they receive. Thus, I endorse Sandra Klenz's recommendation that a media unit be created for Language Arts. Such a unit should include a study of how information technologies - printing presses, telephones, databases, television, VCR's, stereos - affect the form and content of the information we receive. It is obvious, for example, that television news comes in a different form than the morning newspaper, which in turn is different from a newsmagazine. In each case, the form was created to match a specific technological development.

RECOMMENDATION: This relationship between the form of information and technological development must be made a focus of study in a media unit in Language Arts.

The content of information is shaped by social, cultural, and economic forces. Hence, critical analysis of the forces operating on information is necessary. Examining articles for their bias, analyzing commercials for sexist messages, exploring the language structure of an editorial are but a few examples of content analysis.

RECOMMENDATION: The social, cultural, and economic forces impinging on the content of information must be studied in Language Arts.

Literature study offers an excellent route for the exploration of alternatives. In the relative safety of one's own mind, encouraged by well-written prose, students can ponder situations different from their own. If the literature, for example, is based in a time and/or society technologically different from our own, comparisons between the two may suggest how technology changes the society it is housed in. For example, short stories or novels with farm settings could be the jumping-off spot for reflection on questions such as: What happened to horses after the introduction of the tractor? How was life changed when people could use a telephone to communicate over longer distances? How did people store their food in pre-refrigerator days? and so on.

Science fiction of the "gee-whiz," "nuts and bolts" variety is often used to stir and maintain interest in reading. There is another body of science fiction, social science fiction, which explores how societies are shaped by their technologies. This should be included in literature study.

RECOMMENDATION: Prose and poetry which expose children to worlds or cultures technologically different from their own should be included in the language arts curriculum.

Social Studies

If being technologically literate means viewing technology as sociotechnology, then Social Studies has a crucial role to play. The developers of the new curriculum guides (Roots of Society, The Individual in Society, Social Organizations) seem to agree.

I feel the central issue is that of explicating the technology - society interface. Students must study how technological developments have changed societies. In the grade nine social studies curriculum guide, "Roots of Society," unit two deals with technology. Travelling from prehistory through the Renaissance to the present, one of the value positions stated is that of developing an appreciation of the impact of technological change "on the lifestyle, beliefs and values of society" (p. 29). Of equal importance, students must examine how societies have influenced the course of technological development. This latter point is crucial, for if students only study technology's effects on society, it is easy for them to adopt the technological determinist position and feel a sense of loss of control over the direction their society takes. Thus, students must examine the social, political and economic forces which both help and hinder technological development. They must be given the academic tools needed to determine where status and power have resided and currently reside in various societies. The concepts of expertise and expert knowledge should be presented in contexts similar to where students are likely to find it. For example, simulation activities in which various interest groups present their cases over a controversial topic (the site of an oil refinery or a fertilizer plant) could be used. As well, students must be taught how a person in contemporary times takes part in the political process, be it writing a letter to the newspaper or speaking at a public meeting. In the grade eight guide, "The Individual in Society", the previously mentioned grade nine guide, and the grade ten guide, "Social Organizations," citizenship is dealt with. One must take care to ensure that these aspects of society's effects on technology are not portrayed as anti-technology. Rather, society's effects on technology should be seen as

exercising democratic rights on issues that affect the very direction the society will take.

RECOMMENDATIONS:

Social Studies must provide opportunities for studying:

1) the relationship between technology and social change
2) a society's need for experts.
3) citizen action as a necessity in a democracy.
4) an honest perspective on democracy in technological times.

Science

For many, this seems to be the natural home for technological literacy. I feel that, in conjunction with social studies, many of the ideas in the body of this paper can be implemented.

The Background Summary of proposed directions for Science for Saskatchewan Schools matches quite closely the ideals set out in this paper. The nature of the science-technology relationship must be a focal point.

RECOMMENDATIONS:

1) The science-primary position cannot be allowed to continue. Rather, a thorough presentation of R & D must be given.

2) The methods of science and the methods of technology must be explored.

3) The use of scientific information by experts in public debate must be examined. Environmental issues have often served as a springboard for many of these explorations.

4) The concept of "high tech" and its relationship to economic growth should be examined for its implications for scientific research and, in social studies, to determine whether such a relationship exists.

Mathematics

The math curriculum must include units on probability, graphical analysis, and introductory statistics. The units should focus on real world applicability, particularly with regards to the concept of risk. Uncertainty as a standard component of decision making should be introduced.

RECOMMENDATIONS:

1) Calculators in the classroom should be introduced and used in the elementary school

2) The computer should be presented as a tool that is not unique to mathematics

3) Real world applications of probability, uncertainty, graphical analysis, and introductory statistics should be introduced.

Health

There can be little doubt that technological developments have had both positive and negative effects on people's health. To X-ray a suspected fracture or re-attach a retina with a laser are technological commonplaces in medicine. Even closer to home, chlorinating a water supply and freezing food for storage have been major advances in our health care. In many cases, we

seem to focus on medical health care rather than public health care when describing the effects of technology. It is the latter, however, which children encounter and take for granted in their daily lives. Thus, it may be an interesting starting point for the curriculum developer.

Just as well known are the negative effects technological developments have on health. Lead-based paints are harmful to children; lead in car exhaust is harmful to us all. Public health concerns also focus on waste disposal, air quality, automobile safety.

Worker health issues must also be explored. From radiation levels in uranium mines to a farmer's use of a pesticide, the workplace is filled with health hazards directly related to technological development. Not only must these hazards be directly addressed, but also the social and political efforts expended to regulate them must be made explicit. The relationship between economic development and worker health must be explored (perhaps in conjunction with social studies).

RECOMMENDADTIONS:

1) Public health care in the face of technological development must be presented. Bioethics issues should be addressed here.

2) Health care issues in the workplace must be examined.

3) Unit 7 in the Division Three Health Education guide should be expanded to include these.

4) If #3 is not possible, the issues may be best addressed in secondary social studies.

SCOPE AND SEQUENCE CHART

THEMES	LEVEL: Elementary	Middle	Secondary
1) Technical Skills			
a) Calculator	X	X	X
b) Keyboarding	X		
c) Using a computer as a helpful tool			
i) Electronic mail	X	X	X
ii) Work processing	X	X	X
iii) Database use	X	X	X
2) Communication Skills			
a) Reading for information	X	X	X
b) Writing reports	X	X	X
c) Articulating ideas and values orally	X	X	X
d) Effective listening	X	X	X
3) Mathematics skills			
a) Approximating		X	X
b) Use of probalistic reasoning		X	X
4) Meanings for Technology			
a) Personal	X		
b) Civic		X	
c) Cultural			X
5) Goals of Technology			
a) Social goals: Driven by human purpose		X	X
b) Product goals: Hardware	X	X	
6) Doing Technology			
a) Technical	X		
b) Organizational			
i) Social systems of manufacture (economics, trade unions, management of tech)		X	X
ii) Social systems of use (laws, public policy)		X	X
c) Cultural			X

THEMES	LEVEL		
	Elementary	Middle	Secondary
7) The interaction between science and technology: R & D			X
8) Values and technology		X	X
9) People who do technology			
a) Non-stereotypic			X
b) Complex social network with rewards and sanctions			X
10) Technology and decision making			
a) The decision makers inside Technology	X	X	X
b) The decision makers outside Technology	X	X	X
c) The role of the public (see #12)		X	X
d) Risk-benefit analysis (see #10)			X
11) Benefits and costs of technology			
a) Technology assessment			X
b) Appropriate technologies		X	X
c) Decision making and undertainty		X	X
d) Risk analysis			X
e) Technology and the economy			X
f) Public health concerns		X	X
g) Worker health concerns		X	X
h) Social origins of information			X
12) The relationship between technology and society			
a) The relationship is two-way			X
b) Society can influence the shape of future technologies			
i) Funding		X	X
ii) Public policy			X
iii) Special interest groups			X
iv) Legal routes			X

REFERENCES

Barnes, B. (1985). About science. Oxford: Basil Blackwell.

Barnes, B., & Edge, D. (Eds.) (1982). Science in context. Cambridge: The MIT Press.

Bugliarello, G. (1986). Socio-technology: The quest for a new discipline. Science, Technology and Society, 53, 2-5.

Bybee, R. (1985). Science education and the science-technology-society theme. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, French Lick Springs, IN.

Dyrenfurth, M.J. (1984). Literacy for a technological world. Information series no. 266. Ohio State University: National Center for Research in Vocational Education.

Emig, J. (1983). The web of meaning. Upper Montclair: Boynton/Cook.

Fleming, R.W. (1987). High school graduates' beliefs about science-technology-society. II. The interaction among science, technology, and society. Science Education, 71,(2), 163-186.

Fleming, R.W. (in press). Undergraduates studying science: Views on STS of future scientists and non-scientists.

Giroux, H., & Aronowitz, S. (Eds.) (1985). Is computer technology the answer? The crisis in the classroom and educational reform. In Education Under Siege.

Habermas, J. (1971). Toward a national society. London: Heinemann.

Hayter, E.W. (1939). Barbed wire - a prairie invention. Journal of Agricultural History. 13, 189-207.

Kahneman, D., Slovic, P., & Tversky, A. (1982). Judgment under uncertainty: Heuristics and biases. Cambridge: Cambridge University Press.

Kline, S.J. (1985). What is technology? The Bulletin of Science, Technology, and Society, 1, 215-218.

Markle, G.E., & Robin, S.S. (1985). Biotechnology and the social reconstruction of molecular biology. Science, Technology and Human Values, 10(1), 70-79.

Molnar, A. (1986). Common sense about information and information technology. Educational Leadership. 43(6), 64-66.

Mowshowitz, A. (1976). The conquest of will: Information processing in human affairs. Addison-Wesley.

Nisbett, R., & Ross, L. (1980). Human inference: Strategies and shortcomings of social judgment. Englewood Cliffs: Prentice-Hall.

Norman, C. (1981). The god that limps. Science and technology in the Eighties. Toronto: George J. McLeod.

Pacey, A. (1983). The culture of technology. Cambridge: The MIT Press.

Patrick, J.J., & Remy, R.C. (1985). Connecting science, technology, and society in the education of citizens. Boulder: Social Science Education Consortium.

Saskatchewan Department of Education (1984). Computer literacy. Curriculum guide for Division III.

Saskatchewan Department of Education (1984). Computer programming. Curriculum guide for Division IV.

Saskatchewan Department of Education (1984). Computer applications. Curriculum guide for Division IV.

Science Council of Canada (1984). Science for every student: Educating Canadians for tomorrow's world. Ottawa: Minister of Supply and Services.

Smith, R.I. (1983). Technological change and social competence. Paper presented at the Annual Conference of the Social Science Education Consortium, Athens, GA.

Sullivan, E.V. (1983). Computers, culture, and educational futures: A critical appaisal. Interchange, 14(3), 17-26.

U.S. Department of Education (1983). Computers in education: Realizing the potential. Washington: Office of Educational Research and Improvement

Ziman, J. (1984). An introduction to science studies. Cambridge: Cambridge University Press.

BIBLIOGRAPHY*

Alberta Education (1984). Integration of technology in the Alberta science curriculum: A proposal.

Bolton, N. (1985). Technology across the curriculum. Paper presented at the Consultation, St. William's Foundation, York, U.K.

Borgmann, A. (1984). Technology and the character of contemporary life: A philosophical inquiry. Chicago: The University of Chicago Press.

Botting, D., Gerrard, D., & Osborne, K. (1980). The technology connection: The impact of technology on Canada. Vancouver: CommCept.

Bowers, C.A. (1986). Teaching a 19th century mode of thinking through a 20th century machine. Paper prersented at the Faculty Seminar, College of Education, University of Saskatchewan.

Callon, M., Laww, J., & Rip, A. (Eds.) (1986). Mapping the dynamics of science and technology. London: Macmillan.

Durbin, P.L. (Ed.). (1984). Research in philosophy and technology. Volume 7. Greenwich: JAI Press.

Durbin, P.L. (Ed.). (1985). Research in philosophy and technology. Volume 8. Greenwich: JAI Press.

Dyrenfurth, M.J. (1984). Literacy for a technological world. Information series no. 266. Ohio State University: National Center for Research in Vocational Education.

Educational Leadership. (1986). Empowering students and teachers through technology. 43(6), March.

Gordon, D. (1984). The image of science, technological consciousness, and the hidden curriculum. Curriculum Inquiry, 14(4), 467-400.

Government of Canada. (1986). Science and technology indicators 1985. Ottawa: Minister of Supply and Services Canada.

Ihde, Don. (1983). Existential technics. Albany: State University of New York.

Ihde, Don. (1986). Consequences of phenomenology. Albany: State University of New York.

*As well as the works cited in the Reference section, the author's interpretations of the works listed here influenced the writing of this article.

Jonas, H. (1984). The imperative of responsibility: In search of an ethics for the technological age. Chicago: The University of Chicago Press.

Laudam, R. (Ed.). (1984). The nature of technological knowledge. Are models of scientific change relevant. Dordrecht: D. Reidel.

Layton, D. (1985). Some curriculum implications of technological literacy. Paper presented at the Consultation, St. William's Foundation, York, U.K.

Luchsinger, V., & Luschinger, M.L. (1984). Clarifying technology: Its language and use. In R. Ramsey (Ed.), Professional Communication in the Modern World; Preoceedings of the American Business Communication Association Southeast Convention.

MacKenzie, D., & Wajcman, J. (Eds.). (1985). The social shaping of technology. Milton Keynes: Open University.

Nelkin, D. (Ed.). (1984). Controversy: Politics of technical decisions (2nd Edition). Beverly Hills: Sage.

Rothschild, J. (Ed.). (1983). Machina ex Dea: Feminist perspectives on technology. New York: Pergamon.

Smith, R.D. (1983). Technological change and social competence. Paper presented at the Annual Conference of the Social Science Education Consortium, Athens, GA.

Stanley, M. (1978). The technological conscience: Survival and dignity in an age of expertise. New York: The Free Press.

Staudenmeyer, J.M. (1985). Technology's storytellers: Reweaving the human fabric. Cambridge: The MIT Press.

UNESCO (Date unknown). The social relevance of science and technology education. Document series no. 18. Division of Science, Technical, and Environmental Education.

Waks, L.J. and Prakash, M.S. (1985). STS education and its three-step sisters. Bulletin of Science, Technology and Society. 5, 105-116.

Winner, L. (1977). Autonomous technology: Technics-out-of-control as a theme in political thought. Cambridge: The MIT Press.

DESIGNING, PLANNING AND IMPLEMENTATION

1. DESIGNING

1.1 FIT

1.1.1 Can a child perceive (describe, discuss or otherwise communicate) or identify through investigation a fit or misfit between an artifact or system and set of human requirements (desires, needs)?

1.1.2 Can a child judge the quality of the fit or misfit ('How well does it work?) and express this judgement?

1.1.3 Can a child recognize that something might be done to improve, rectify or change an artefact, or if there is a good fit, to leave things as they are?

1.1.4 Can a child identify criteria which are relevant to improving the quality of fit?

1.2 HOLISM

1.2.1 Can a child analyse a misfit ('Design problem') in such a way that he takes into account such factors and considerations as:

i) Economic (cost, time, availability of materials).

ii) Social (awareness of others and of the effect of the designed artifact/systeem upon them).

iii) Ethical (morality of proposed change).

1.2.2 Can a child mould all the aspects of a design problem in a balanced, interactive way?

1.2.3 Can a child fit ends to means as well as means to ends?

1.3 FORMULATION

1.3.1 Can a child state or restate the design problem? (In order to arrive at its essence.)

1.3.2 Can a child look at a particular solution and work backwards to reformulate the original problem?

1.3.3 Can a child generate a variety of possible provisions (solutions) to a design problem?

1.4 CONVERGENCY

1.4.1 Can a child decrease the variety of possible solutions and show commitment to a specific, practical proposal?

1.4.2 Can a child explain and justify the reason for his choice of one in preference to others?

1.5 DATA SEARCH

1.5.1 Can a child recognise the need for the collection of information which is appropriate to the problem?

1.5.2 Can a child search for, generate, collate and judge the reliability and usefulness of information?

1.5.3 Can a child apply the relevant information, which he has obtained, to aid the solution of the problem?

1.6 IMAGING OR COGNITIVE MODELLING

1.6.1 Can the child conjure up a description of an artefact, system (or parts of such things) in the mind's eye?

1.6.2 Can he manipulate the images? (Rotate, assemble, change colour or texture, cause interpenetration or change form.)

1.6.3 Can the child express these images? (Sketch, model, etc.)

1.7 DESIGN MODELLING

1.7.1 Can a child demonstrate the purpose of modelling? (Iconic, symbolic, analogue.)

a. to simplify (by reduction to essentials)
b. to show correspondence (eg. by analogy)
c. to give emphasis (e.g. to salient features)
d. to extrapolate (eg. trends)
e. to simulate (eg. lighting change)

1.7.2 Can a child detect the limit of usefulness of a form of modelling? (eg. when scaling down invalidates a model.)

1.7.3 Can a child translate one form of model or simulation to another form or to reality? (eg. circuit diagram to assembled components.)

2. PLANNING, IMPLEMENTATION AND EVALUATION

2.1 PLANNING

2.1.1 Can a child cost the production of an artefact or system? (In terms of use of material resources, time, energy, social effects.)

2.1.2 Can a child distinguish between the difference of producing a single artefact or manufaccturing for bulk production?

2.1.3 Can a child plan a sequence of operations in an appropriate order which will lead to the production of an artefact or system?

2.2 IMPLEMENTATION

2.2.1 Can a child demonstrate that he is alert to the possibility that an unforeseen difficulty may arise during making which may indicate an alternative means of realisation or production?

2.2.2 Can a child deal effectively with such difficulties by acquiring new strategies, information or skills?

2.2.3 Can a child execute a task with due regard to the need for safe practice?

2.2.4 Can a child choose and use appropriate tools, materials and appliancces to acchieve his purpose?

2.3 EVALUATION

2.3.1 Can a child evaluate and offer a continuing critique on the process and progress of his design?

2.3.2 Can a child re-evaluate at the conclusion of realisation (after a suitable interval of time) the quality of the match between design and need?

2.3.3 Can a child analyse and evaluate the approach and solution adopted by other designers?