



this **ACIATE/CTTE yearbook** was

scanned at the department of

Technology and Engineering Education,

Central Connecticut State University



...by Johnny Kassay and Pat Foster from the collections of several educators, including David Sianez and James DeLaura.

Responsibility for any copyright infringement is claimed by Patrick N. Foster. We plan to improve this document by re-scanning, adding links, and/or direct neural input.

TECHNOLOGICAL LITERACY

1991

*Council on Technology
Teacher Education*

40th Yearbook

TECHNOLOGICAL LITERACY

EDITORS

Michael J. Dyrenfurth

University of Missouri-Columbia
Columbia, Missouri

Michael R. Kozak

University of North Texas
Denton, Texas

40TH YEARBOOK, 1991

Council on Technology
Teacher Education

Copyright © 1991 by the Council on Technology Teacher Education. All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying or recording, or by any information storage and retrieval system, without permission in writing from the Publisher.

Glencoe Division, Macmillan/McGraw-Hill

809 West Detweiller Drive
Peoria, IL 61615-2190

Printed in the United States of America

Orders and requests for information about cost and availability of yearbooks should be addressed to the company.

Requests to quote portions of yearbooks should be addressed to the Secretary, Council on Technology Education, in care of the publisher, for forwarding to the current Secretary.

**This publication is available in
microform.**

University Microfilms International

300 North Zeeb Road
Dept. P.R.
Ann Arbor, MI 48106

ISBN 0-02-677119-5

FOREWORD

Technological literacy assumes increasing importance as technology educators seek to prepare young persons to meet the challenges of the future. Yearbook 40, *Technological Literacy*, suggests directions for the field and provides strategies for initiating effective programs for the development of technological literacy.

The editors, Michael J. Dyrenfurth and Michael R. Kozak, and the chapter authors have provided the profession with a valuable resource. This volume will assist readers in moving toward better understanding of the relationship between technological literacy and technology education.

The model of technological literacy presented in this volume has been developed by utilizing the perspectives of technology educators as well as the viewpoints of individuals from other professions. The volume presents a sound philosophy that addresses the demands of the future. The authors and editors have been successful in their efforts to conceptualize and implement unique technology education programs designed to develop technological literacy.

Yearbook 40 also addresses implementation procedures. Well-designed instructional strategies must be grounded in a clear sense of purpose. Programs must also respond to the mission of the educational enterprise in preparing individuals to meet the challenges of an uncertain future. The authors and editors suggest approaches which have demonstrated success in practice and which offer promising prospects for future development.

Finally, Yearbook 40 includes a critique of its content and offers suggestions for future directions of the profession. The volume provides a dynamic springboard for continuing efforts to develop technological literacy through technology education.

The Council on Technology Teacher Education commends Michael J. Dyrenfurth and Michael R. Kozak for conceptualizing this volume, organizing its preparation, and carrying out the editorial processes to bring this valuable work to the profession. The Council also recognizes the significant contributions of the chapter authors, whose efforts provide the main thrust of the yearbook. Appreciation is expressed to Glencoe/McGraw-Hill for continuing its long-term record of support to the profession by underwriting the cost of the publication.

Daniel L. Householder

President, CTTE
March, 1991

OFFICERS OF THE CTTE

President

Daniel L. Householder
Department of Industrial,
Vocational, and Technical
Education
Texas A&M University
College Station, TX 77843

Vice-President

Jane Liedtke
Department of Industrial
Technology
Illinois State University
Normal, IL 61761

Recording Secretary

Betty L. Rider
College of Education
The Ohio State University
Columbus, OH 43210

Membership Secretary

Gerald L. Jennings
Department of Business
and Industrial Education
Eastern Michigan University
Ypsilanti, MI 48197

Treasurer

Emerson Wiens
Department of Industrial
Technology
Illinois State University
Normal, IL 61761

Past President

R. Thomas Wright
Department of Industrial
Technology
Ball State University
Muncie, IN 47303

YEARBOOK PLANNING COMMITTEE

Terms Expiring in 1991

Donald P. Lauda
California State University -
Long Beach
John R. Wright
Central Connecticut State University

Terms Expiring in 1992

Donald Maley
University of Maryland
Ronald E. Jones
University of North Texas

Terms Expiring in 1993

Paul W. DeVore
West Virginia University
Everett Israel
Eastern Michigan University

Terms Expiring in 1994

Anthony E. Schwaller
St. Cloud State University
Robert Wenig
North Carolina State University

Terms Expiring in 1995

Richard Henak
Ball State University
James E. LaPorte
Virginia Polytechnic Institute
and State University

Chairperson

R. Thomas Wright
Ball State University

YEARBOOK PROPOSALS

Each year, at the ITEA International Conference, the CTTE Yearbook Committee reviews the progress of yearbooks in preparation and evaluates proposals for additional yearbooks. Any member is welcome to submit a yearbook proposal. It should be written in sufficient detail for the committee to be able to understand the proposed substance and format. Fifteen copies of the proposal should be sent to the committee chairperson by February 1 of the year in which the conference is held. Below are the criteria employed by the committee in making yearbook selections.

CTTE Yearbook Committee

Guidelines for CTTE Yearbook

A. Purpose:

The CTTE Yearbook Series is intended as a vehicle for communicating education subject matter in a structured, formal series that does not duplicate commercial textbook publishing activities.

B. Yearbook topic selection criteria:

An appropriate Yearbook topic should:

1. Make a direct contribution to the understanding and improvement of technology teacher education.
2. Add to the accumulated body of knowledge of the field.
3. Not duplicate publishing activities of commercial publishers or other professional groups.
4. Provide a balanced view of the theme and not promote a single individual's or institution's philosophy or practices.
5. Actively seek to upgrade and modernize professional practice in technology teacher education.
6. Lend itself to team authorship as opposed to single authorship.

Proper yearbook themes **may** also be structured to:

1. Discuss and critique points of view which have gained a degree of acceptance by the profession.
2. Raise controversial questions in an effort to obtain a national hearing.
3. Consider and evaluate a variety of seemingly conflicting trends and statements emanating from several sources.

C. The yearbook proposal:

1. The Yearbook Proposal should provide adequate detail for the Yearbook Planning Committee to evaluate its merits.
2. The Yearbook Proposal should include:
 - (a) An introduction to the topic
 - (b) A listing of chapter titles
 - (c) A brief description of the content or purpose of each chapter
 - (d) A tentative list of authors for the various chapters
 - (e) An estimate of the length of each chapter

PREVIOUSLY PUBLISHED YEARBOOKS

- *1. *Inventory Analysis of Industrial Arts Teacher Education Facilities, Personnel and Programs*, 1952.
- *2. *Who's Who in Industrial Arts Teacher Education*, 1953.
- *3. *Some Components of Current Leadership: Techniques of Selection and Guidance of Graduate Students; An Analysis of Textbook Emphases*; 1954, three studies.
- *4. *Superior Practices in Industrial Arts Teacher Education*, 1955.
- *5. *Problems and Issues in Industrial Arts Teacher Education*, 1956.
- *6. *A Sourcebook of Reading in Education for Use in Industrial Arts and Industrial Arts Teacher Education*, 1957.
- *7. *The Accreditation of Industrial Arts Teacher Education*, 1958.
- *8. *Planning Industrial Arts Facilities*, 1959, Ralph K. Nair, ed.
- *9. *Research in Industrial Arts Education*, 1960. Raymond Van Tassel, ed.
- *10. *Graduate Study in Industrial Arts*, 1961. R. P. Norman and R. C. Bohn, eds.
- *11. *Essentials of Preservice Preparation*, 1962. Donald G. Lux, ed.
- *12. *Action and Thought in Industrial Arts Education*, 1963. E. A. T. Svendsen, ed.
- *13. *Classroom Research in Industrial Arts*, 1964. Charles B. Porter, ed.
- *14. *Approaches and Procedures in Industrial Arts*, 1965. G. S. Wall, ed.
- *15. *Status of Research in Industrial Arts*, 1966. John D. Rowlett, ed.
- *16. *Evaluation Guidelines for Contemporary Industrial Arts Programs*, 1967. Lloyd P. Nelson and William T. Sargent, eds.
- *17. *A Historical Perspective of Industry*, 1968. Joseph F. Luetkemeyer, Jr., ed.
- *18. *Industrial Technology Education*, 1969. C. Thomas Dean and N. A. Hauer, eds. *Who's Who in Industrial Arts Teacher Education*, 1969. John M. Pollock and Charles A. Bunten, eds.
- *19. *Industrial Arts for Disadvantaged Youth*, 1970. Ralph O. Gallington, ed.
- *20. *Components of Teacher Education*, 1971. W. E. Ray and J. Streichler, eds.
- *21. *Industrial Arts for the Early Adolescent*, 1972. Daniel L. Householder, ed.
- *22. *Industrial Arts in Senior High Schools*, 1973. Rutherford E. Lockette, ed.
- *23. *Industrial Arts for the Elementary School*, 1974. Robert G. Thrower and Robert D. Weber, eds.
- *24. *A Guide to the Planning of Industrial Arts Facilities*, 1975. D. E. Moon, ed.
- *25. *Future Alternatives for Industrial Arts*, 1976. Lee H. Smalley, ed.
- *26. *Competency-Based Industrial Arts Teacher Education*, 1977. Jack C. Brueckman and Stanley E. Brooks, eds.
- *27. *Industrial Arts in the Open Access Curriculum*, 1978. L. D. Anderson, ed.
- *28. *Industrial Arts Education: Retrospect, Prospect*, 1979. G. Eugene Martin, ed.
- *29. *Technology and Society: Interfaces with Industrial Arts*, 1980. Herbert A. Anderson and M. James Benson, eds.
- *30. *An Interpretive History of Industrial Arts*, 1981. Richard Barella and Thomas Wright, eds.
- *31. *The Contributions of Industrial Arts to Selected Areas of Education*, 1982. Donald Maley and Kendall N. Starkweather, eds.
- *32. *The Dynamics of Creative Leadership for Industrial Arts Education*, 1983. Robert E. Wenig and John I. Mathews, eds.
- *33. *Affective Learning in Industrial Arts*, 1984. Gerald L. Jennings, ed.
- *34. *Perceptual and Psychomotor Learning in Industrial Arts Education*, 1985. John M. Shemick, ed.
- *35. *Implementing Technology Education*, 1986. Ronald E. Jones and John R. Wright, eds.
- *36. *Conducting Technical Research*, 1987. Everett N. Israel and R. Thomas Wright, eds.
- *37. *Instructional Strategies for Technology Education*, 1988. William H. Kemp and Anthony E. Schwaller, eds.
- *38. *Technology Student Organizations*, 1989. M. Roger Betts and Arvid W. Van Dyke, eds.
39. *Communication in Technology Education*, 1990. Jane A. Liedtke, ed.

*Out-of-print yearbooks can be obtained in microfilm and in Xerox copies. For information on price and delivery, write to Xerox University Microfilms, 300 North Zeeb Road, Ann Arbor, Michigan, 48106.

CONTENTS

Foreword	iii
Officers of the Council	iv
Yearbook Planning Committee	iv
Yearbook Proposals & Guidelines	v
Previously Published Yearbooks	vi
Contents	vii-viii
Preface	ix
Acknowledgements	x
Prologue	1

Section I:

Technological Literacy in Context8

This section is designed to set the stage for an in-depth treatment of the concept of technological literacy and its implications for education and implementation.

Chapter 1

The Natures and Challenges of Technological Literacy ..10

Ronald D. Todd

Chapter 2

Education *About* Technology28

Michael R. Kozak & Janet Robb

Section II:

Key Perspectives on Technological Literacy51

This section's primary intent is to bring "outside" perspectives to the field. The objective is to enrich the scope and perspectives of our view of the key outcome of our profession's practice — namely technological literacy.

Chapter 3

International Perspectives on Technological Literacy ...54

Jule D. Scarborough

Chapter 4

Economic Perspectives on Technological Literacy80

David W. Stevens

Chapter 5	
	Labor, Private Sector, and Governmental Perspectives on Technological Literacy94
	James L. Barnes & Thomas L. Erekson
Chapter 6	
	Educational Perspectives on Technological Literacy ...119
	M. James Bensen
Chapter 7	
	Technological Literacy Synthesized138
	Michael J. Dyrenfurth
<hr/>	
Section III:	
	Technological Literacy: Implications for Practice184
	This section focuses on the implications, of the perspectives on technological literacy and its models, for the practice of the profession, i.e., where practitioners encounter students. The section ends with a chapter that raises questions and offers guidelines for technological literacy implementation challenges by the year 2030 AD.
Chapter 8	
	Implementation of School-Based Technology Education Programs187
	Robert Daiber, Les Litherland & Terry Thode
Chapter 9	
	Support Activities for Implementing Technology Education Programs.....212
	Roger Stacy & Harry Tobin
Chapter 10	
	The Challenge for Technology Teacher Education Programs239
	Larry Hatch & Ronald Jones
Chapter 11	
	Technological Literacy: The Evolving Paradigm251
	Paul W. DeVore
Compiled References280
Bibliography300

PREFACE

Technology has been defined. Technology education has been implemented. Characteristics of technologically literate persons have been enumerated. The concept of technological literacy is increasingly employed by many people, both within the profession and outside. Despite all, there clearly remains a sense of urgency to clarify the concept of technological literacy upon which so much is based. This is particularly urgent as the technological pressure experienced by all members of our world is escalating rapidly.

This yearbook, believed to be the first text solely focused on technological literacy, is dedicated to clarifying and advancing existing conceptions of this concept. It seeks to bring outside ideas into our profession. It reviews a state-of-the-art information search, includes a large scale synthesis of the issues, and provides extensive discussion of implications central to the education of America's youth and adults. Included are perspectives that have a direct influence upon the conduct of education and business. Among these, in addition to those of educators, are the views of international practitioners, labor, government, and the private sector. Our goal is to present the multiple perspectives, definitions, and models in a way that engenders increased levels of precision in usage, clarity of meaning and effectiveness of communication.

The yearbook is crafted in three sections. The first, **Technological Literacy in Context**, examines the overall perspective that locates the concept in its environment. Subsequently, Section II, **Key Perspectives on Technological Literacy**, brings a fresh set of perspectives to the profession. Business, industry, labor, economic, and international views are presented as are those of the educational community. The second section concludes with a systematic synthesis resulting in a proposal for a new model of technological literacy. The third section, **Technological Literacy: Implications for Practice**, is designed to highlight key implications of technological literacy for practice. Leading teachers, teacher educators, and supervisors share their views on implementing programs that address technological literacy. The capstone chapter then projects a long-range view to keep our profession, and the concept of technological literacy, fresh!

Michael J. Dyrenfurth
Michael R. Kozak

ACKNOWLEDGEMENTS

Grateful appreciation is extended to the many individuals whose contributions made this book a reality. Their valuable assistance was of immeasurable help in accessing documentation, formulating positions and clarifying them. In particular, the chapter authors must be singled out for special recognition—after all, it is their work that made this yearbook! Their insight, expertise and effort truly made it possible to offer this yearbook to the profession as a significant step forward.

The members of the Council's Yearbook Committee were demanding when they had to be, immensely helpful when called upon, and always professional. Their standards for clarity and centrality of purpose were major factors helping the editors formulate and pursue this challenge.

To Glencoe/McGraw-Hill, the editors extend sincere appreciation for their ongoing commitment to the technology education profession. Their assistance, encouragement and support is inexorably tied to the profession's advancement.

Paul DeVore must be recognized for two particularly important contributions beyond those represented by this yearbook's concluding chapter. First, he is **the** persona of the intellectually active and capable leader of our profession. Second, he again took time from his intense schedule to help with a critical review of this yearbook's draft chapters. Similarly, a special note of gratitude must also be offered to Wes Stephens for his particularly useful editorial assistance and for his unflinching willingness to serve the profession. The word processing of UMC's College of Education's Sue Merritt and Angie Bowden and Industrial Education's Donna Perry, Denise Aholt, and Shannon Monnig made a difficult task much more manageable as did the research of James Helmick and Yusuf Al-Hassan. Also the support of the editors' home institutions, deans, departments, chairs, and colleagues represent a contribution that typifies their ongoing encouragement of professional contributions.

Finally, any success we two M's may have in our professional careers is based on the strength and support of two other most important M's (Mary and Monica).

Michael J. Dyrenfurth
Michael R. Kozak

PROLOGUE

Michael Dyrenfurth, Larry Hatch, Ronald Jones, Michael Kozak

WHAT IS TECHNOLOGICAL LITERACY?

This entire yearbook addresses this question: What is technological literacy? Although not overwhelmingly popular when first raised, in either the technology education profession or elsewhere, the concept's use has escalated geometrically. So much so, that some concern has been stimulated about whether the concept is actually **legitimate** or if it is just another **fad**, or to use Todd's (1991) term, **slogan**, that sweeps across American education. Given this, it becomes critically important to address the question of significance of the concept (technological literacy) before too much more time and resources are expended and before the lives of future generations are jeopardized.

Obviously, the very fact that the CTTE has selected the concept as being worthy of joining the ranks of its other significant publications lends some credibility, but, it is no guarantee of legitimacy. Associations, just like individuals, are susceptible to **herd** behavior. Therefore, the merits of the arguments must establish the legitimacy of the concept and its definition.

SIGNIFICANCE, IMPORTANCE, AND JUSTIFICATION OF TECHNOLOGICAL LITERACY

The significance of the concept of technological literacy was investigated by reviewing literature in the fields of social policy/commentary, technology, science, and liberal arts/humanities. The authors reviewed such documents and analyzed if, and how, technological literacy or its root ideas could be found.

The review¹ of the concept's significance resulted in six categories of reasons; each concluding with an affirmative vote in favor of significance. These categories were: (1) democratic needs, (2) nature of life in

¹One caveat must be recognized. The authors' review was purposeful not random. Given this, it is to be expected that the term technology, and references to it, surfaced frequently.

society, (3) dehumanization/humanization, (4) new liberal arts directions, (5) nature of jobs/competitiveness/workforce literacy, and (6) technology as a discipline. These six individual conclusions combine to present a powerful argument for the significance of technological literacy.

Democratic Needs

First among the reasons for technological literacy are those that pertain to the essential elements and nature of our society. Clearly we subscribe to the ideals that follow from our commitment to democracy. This commitment and goal carries with it significant responsibility. DeVore (1987) noted this by stating:

A technological society is based upon **knowledge** and **know-how**. As our society has progressed technologically we have become aware that a new form of literacy is required if all citizens are to function effectively as **free** and **responsible** members of the society (p. 9).

Similarly, Smalley (n.d.) in his revised technological literacy test document, cites Richter (1980):

In a democracy, where the claim is that all people should have a right to determine their future, a citizenry that is knowledgeable of technology is important. Therefore, as a part of their general education citizens should study fundamental technological systems as routinely as they acquire other skills for literacy.

Nature of Life in Society

Today's way of life, regardless of political system, demands capability with, and understanding of, technology. "Survival of the human is dependent upon the human's capacity to apply rationality in solving problems within the environment. To accomplish this, every society, even the most primitive, relies on scientific and technological pursuits in its daily existence" (Pytlik, Lauda, & Johnson, 1985, p. 3).

Echoing this position, the American Association for the Advancement of Science (AAAS) (1985, October) cited the Exxon Education Foundation-organized conference that resulted in the 1984 report: *Science education in the United States: Essential steps for achieving fundamental improvement*. In it, they noted: "Scientific and technologi-

cal understanding is a key to adjusting to and participating in a world that will continue to change rapidly technologically for the foreseeable future. Because these changes occur in all realms of life—work, civic affairs and personal—the case that such education is relevant to virtually all Americans seems compelling (p. 7)" (p. 5).

In this country, the private sector also is sensitive to the demands our lifestyle generates for technological capability. Even more importantly, business leaders note that **education**, i.e., **our** world, should do something about this. Anton Campanella, President of New Jersey Bell, stated on May 14, 1987, "we need to get technology education universally on line so every student has an opportunity to become technologically literate." His company felt so strongly about this, that in an enclosure received by every customer they stated: "Technological literacy gives people the ability to learn about technology so they can accommodate it when it surfaces in their lives. The goal is technological literacy for everyone" (New Jersey Bell, 1988).

Dehumanization / Humanization

Among others, the idealists and existentialists concern themselves with questions about humankind's nature and factors that might tend to dehumanize us. Clearly technology, even when not necessarily misapplied as argued by Rifkin (1987) in *Time wars*, can and does dehumanize. His point is that technology, using the everyday clock as a compelling metaphor, has dehumanized life by its increasing demands on the human—demands the human does not control.

A healthy understanding of technology and its nature might well empower humankind to resist such easy fallacies as "blaming the machine" by forcing acknowledgement of reality, i.e., that it is people who make decisions ultimately.

New Liberal Arts (NLA) Directions

MIT's Provost, John M. Deutch states "besides practical reasons for technological literacy, I worry about a more subtle matter. The difference in how the imagination is perceived to come into play in science and technology, compared to the liberal arts, bears much of the blame for the lack of sympathy for technology among non-scientists ... how to expand understanding of technology in human affairs is one of my foremost concerns. Technological literacy warrants greater prominence in liberal arts programs which are still almost devoid of its influence" (1986, p. 1).

It is important to recognize that not everyone is enamored of the role of technology and education for it. For example, authors such as those collected by Feinberg & Rosemont (1976) suggest that "schools have succeeded too well in adapting the young into a corporate, technologically complex society" and that this harms creativity. They instead consider schools the "memory bank" of society. These authors would join the long forgotten author who, in the *New York Times* no less, suggested the liberal arts would be better off without tampering, such as the addition of technology and the "new liberal arts." Such dissent notwithstanding, the NLA movement is certainly not to be discounted in the foreseeable future.

Nature of Jobs/Competitiveness/Workforce Literacy

Setting ideals, and the liberal arts and humanities aside, the harsh necessities of life (to many, work and employment) demand attention to technology as well. Hoyt (1988, p. 2) observed, that the "skill level required for occupational success will increase with both the content and complexity of jobs being modified by technological change. Thinking even more globally, Kuilman (1989, p. 5), a senior Dutch Phillips executive, in opening the international Pupils Attitude Toward Technology (PATT) IV conference observed:

- "each employee has to have a certain basic knowledge of, and basic skills in technology, apart from his or her special vocational education;
- each citizen living in this society has to have a certain basic technological knowledge to be able to function in society; and
- "a broadly founded basic knowledge of technology is desirable to develop an understanding of the social usefulness of a well-functioning modern industry."

Because of the demand for competitiveness, Dyrenfurth et al. (1989) were commissioned by the joint educational development and training agency of a major union and manufacturer (*Fortune* top ten), to synthesize and assemble a cogent picture of the views of leading authorities of the skills expected to be crucial to the industrial workforce of the future. In particular, the focus was on the clarification of the requirements for technological literacy. Systematic analysis of documents, primarily national in scope, but with some key international items, drawn from the management, engineering, and popular literature domains revealed six major trends as bearing on the skills expected of the future workforce:

- a shift towards worker empowerment will take place;
- increased computer automation and integration will occur;
- an an ongoing shift from uniform mass production to flexible small batch production;
- continuation of a significant human presence in manufacturing;
- increasing expectations for workers to have a polyvalent arsenal of skills; and
- more frequent use of new forms of enterprise (work organization and hierarchy).

Technology As a Discipline

With the pervasiveness of technology in today's world, it is no wonder that serious work has taken place on the matter of technology's "declaration of independence." For example, both DeVore (1985) and the AAAS (October 1985, pp. 7-8) have advocated such a move. In their Phase I, Project 2061 report, the AAAS demonstrated its concern for the equitable treatment of technology as a subject by stating its goal "that some integrated attention will be given to technology, and that it can be considered in its own right, beyond its interplay with the sciences" (p. 11).

SUMMARY

Despite widespread recognition of the importance of the subject of technology, apparently it is not yet pervasive enough. Take, for example, the Congressional Office of Technology Assessment's 1988 report, *Power on! New tools for teaching and learning*. The entire 246-page document, commissioned by the House Committee on Education and Labor, omits any cogent discussion of education **about** technology. Instead, the ongoing love affair of educational administrators and bureaucrats for a "quick fix" via new instructional media is repeated and the entire document focuses on education **with** technology.

If thousands of years of formal and informal schooling have transpired without any systematic treatment of technology, why should we start now? Many others feel that traditional fields, e.g., science, are adequate to address the situation. The authors posit that this is a serious misreading of the problem or a lack of precision in the use of words.

Even as senior an official as Erich Bloch, director of the National Science Foundation, fails to demonstrate the insight needed to address the nation's well-recognized crisis in technological capability. In commenting on findings of the International Association for Evaluation of Educational Achievement's report that showed a dismal performance for the USA's students, he said "these findings emphasize again the troubled state of science education in the United States ... America's future as a world technological and economic leader, and the quality of life we enjoy, depend on confronting the real problems in science education with vigor, determination and a sense of urgency." (*Columbia Daily Tribune* (MO), March 6, 1988, p. 26). The problem is clearly his recognition of a **technology deficit** yet his positing of a **science fix**.

CONCLUSION

The call for technological literacy as the new basic for the 21st century has become the rallying cry of the technology education profession. Both the International Technology Education Association (ITEA) and the Technology Education Division of the American Vocational Association (AVA) have made it a major goal of their programs of work. Promotional videos detail the need for technological literacy. Tests have been piloted to measure technological literacy. Symposia have debated its meaning. As a profession, we believe it is important. Yet, we are experiencing difficulty in establishing a coherent and consistent definition, let alone, implementation.

Three dimensions of scientific literacy have been identified: (a) practical, (b) civic, and (c) cultural. These dimensions involve being able to use, knowing about, and appreciating the role of science. Scientific literacy encompasses all of these attributes, not just any one. Similarly, technology educators must also recognize the multiple dimensions of technological literacy if, as a profession, we are going to move from debate to a logical course of action. A coherent definition would enable the profession to identify needs and set goals for new content and methodology in the teacher education curriculum.

TECHNOLOGICAL LITERACY: A NEW PARADIGM

Examining the meaning of the term **technological literacy** from an entirely new vantage points creates the opportunity for new paradigms. The conceptualizing and development of this yearbook provided such an opportunity for the editors and authors. Reading and analysis of its chapters empowers members of the profession to do the same. To begin this process, we advance the following initial characterizations of technological literacy:

Technological literacy is a multi-dimensional term that necessarily includes *the ability to use technology* (practical dimension), the ability to understand the issues raised by or use of technology (civic dimension), and the appreciation for the significance of technology (cultural dimension).

SECTION I

Technological Literacy in Context

This section introduces the concept of technological literacy, its meaning and context. The concept's evolution is traced and its essential features are highlighted. Also incorporated is a discussion of the myths and misconceptions associated with technological literacy.

Technological literacy is experiencing ongoing and exponential evolution. Consequently, it cannot be defined as a static phenomenon. Therefore, in addition to a brief synopsis of the current context of technological literacy, this section communicates the imperative that future implications be addressed. These implications include the permutations of problems and promises that challenge our technology education profession plus the genesis **of a new educational mandate that transcends the original goals of technological education.** Like its content base of technology, technology education is continually evolving!

Chapter one addresses the nature and challenges and, in doing so, it establishes the content for Section II, which brings many of the outside perspectives to our profession. Chapter two addresses many of the essential elements of effective technology education practice. In doing so, it establishes the content for Section III, which highlights the approaches of three exemplary sets of practitioners.

Education about technology has long been conceived as an integral aspect of the general education curriculum. Among the challenges addressed by technology education are an accelerating rate of technological change, society's utilization of developed technology, unequal distribution of technological capabilities, as well as the difficulty in understanding the phenomenon of technology itself.

The purposes of America's schools reflect the challenge of an education that is much more encompassing and pluralistic than **only** a study of technology. However, American schools clearly must include an education about technology in order to empower citizens to use this most potent force. Technology education is an essential curriculum

strand that flows from elementary through university levels and beyond. Effectively implemented, this approach, unanimously supported by today's major technology education professional associations, will lead to a curriculum whose intrinsic merit will be documented by the testimony and actions of a technologically literate populace.

CHAPTER ONE

THE NATURES AND CHALLENGES OF TECHNOLOGICAL LITERACY

by
Ronald D. Todd¹

Technological literacy is a term of little meaning and many meanings. It is a vision that has national, even international, attention and appeal. It is a slogan of immense potential power for creating interest and commitment and it can serve as a theme underscoring the shortage of technologically capable people. Indeed, it is a concept in conflict—conflict of meaning, use, and potential.

Technological literacy is also a concept of beguiling and misleading simplicity. It has the capacity to charm as well as to deceive. Education agencies generally, and educators more specifically, are vulnerable to such concepts. Our profession is drawn to the apparent simplicity and the potential power of the idea of technological literacy. We all wish to be literate, and we all work to be technologically literate. Who would argue with helping students become literate about one of the major forces that shapes the world in which they live? Yet, who proposes generally acceptable plans to accomplish these ends? What really are the ends or goals of technological literacy? Obviously many problems reside in and among the initial ideas, the proposed actions, and the anticipated ends of technological literacy.

But technological literacy is about more than education and schooling. It is also about politics and economics. But most of all, technological literacy is a new cry for the relevance of learning—a cry that represents a societal mandate for technology education.

¹Ronald D. Todd is Research Professor, College of Design Arts, Drexel University, Philadelphia, Pennsylvania.

THE MULTIPLE MEANINGS OF TECHNOLOGICAL LITERACY

One of the first problems that faces the profession in dealing with technological literacy is the ambiguity that resides in the term. There are several reasons for this ambiguity, but the most significant is the lack of understanding of what role technological literacy is to play in the efforts of our profession's. Currently we are unsure whether we are using technological literacy to represent a slogan, a concept, a goal, or a program. Each of these four uses is important to education. Each engenders a different role. Each requires a different level of understanding by those who would translate it into action.

If we are to use the idea of technological literacy, it is important that we should continue to clarify its meaning as well as its use and potential (Scarborough & Blankenbaker, 1983; Foster & Perreault, 1986), rather than discard it as has generally been the practice by science educators with the concept of **scientific literacy**. The intent of this chapter, indeed, of this yearbook, is to elevate the understanding of technological literacy to new levels of usefulness for the profession.

Technological Literacy As a Slogan

As a slogan, technological literacy is useful as a battle flag around which people can rally. Technological literacy as a slogan can also be translated into a battle cry to mobilize action. To remain useful, however, slogans must remain undefined. The purposeful vagueness of technological literacy is an advantage. It allows potential supporters to join the cause and to represent their own meanings, and their own values within the term. A clear and specific definition might exclude people who could accept the slogan but would reject a specific, stipulated meaning. Specificity and clarity would be undesirable, therefore, if they excluded people from joining the cause.

Waks (1986) struck to the core of this issue in his summary statement as editor of the report of the proceedings of the First National Conference on Technological Literacy. "The term technology literacy is best thought of as a slogan. It has little specific content, but it has a definite emotional appeal" (p. 321). He continued with the observation that:

The use of slogans makes it possible to unite very disparate groups around common themes. We can all agree that we live in a highly technological environment, that it would be desirable for young people to obtain new knowledge and skills to adapt to this environment. Though various groups may differ about what they want young people to learn, they can at least agree that without some intervention no group will get what it wants. Hence they can all join forces in calling out for "technological literacy" now, hoping to shape the programs generated by the "literacy" war cry to fit their values and needs later on. This makes a loosely coordinated national effort possible (p. 332).

Technological Literacy As a Concept

If the intent is to encourage professional discussion, then meaning rather than emotion will be the major criterion for technological literacy as a concept. Technological literacy as a slogan with its characteristics of ambiguity and emotionality confuses rather than clarifies. Instead, clarity of meaning and rationality of thought can reside in a well-crafted concept of technological literacy. Such concepts, as theoretical constructs, can work at one or more levels and fulfill one or more of the several functions identified in Figure 1-1.

LEVELS	FUNCTIONS
1	Exploration
2	Description
3	Explanation
4	Prediction
5	Control

Figure 1-1. Levels and functions of theoretical constructs.

Each of the levels represents concepts or constructs of progressively greater power. Initially it may be important to maintain and use selected concepts at some of the lower levels. For example, Waks (1986, p. 332) suggested that premature closure on the meaning of technological literacy could hamper curriculum development efforts. He states that

"the term 'technological literacy' has an heuristic value, capable of stimulating imaginative curricular frameworks." The heuristic capacity of technological literacy falls within the exploration or Level 1 function of technological literacy.

Roy (1986) and Todd (1986) both proposed that it was time to clarify and extend the meanings and use of technological literacy. One of the reasons for the lack of clarity of the term **technological literacy**, stems directly from the relative lack of clarity of the term **technology**. Since the meanings of technology remain unclarified, so consequently technological literacy remains vague also. The use of "meanings" in the plural sense is intentional. At this point in time, few common definitions, and certainly no common programs of technology, have been adopted. While common programs are not necessary or perhaps even desirable, common meanings and definitions, however, are essential.

Technological Literacy As a Goal

Until recently little has been said directly about technological literacy as a goal. This does not mean, however, that technological literacy as a goal is new. Indeed it appears that the idea of technological literacy provided a descriptor or even a timely rationale for goals already in place for technology education. As a goal, technological literacy will need considerably more clarity than is currently the case. Hopefully, some of the desired clarity will be achieved through efforts to clarify, assess, and measure what technological literacy actually is (DeVore, 1986; Smalley, 1986; Wright, 1980). Although a growing body of work has been mounted, no general goal profile has emerged, and perhaps none will. In any case, increased attention to the assessment and quantification of technological literacy should serve to extend much needed professional dialogue on the scope of technological literacy as a goal.

Technological Literacy As a Program

Lately, there has been an emergence and proliferation of programs that purport to help deliver technological literacy. One of national significance is the Science, Technology and Society (STS) thrust. STS programs have built upon the excitement generated by the use of technological literacy as a slogan and have helped to increase the visibility of technology-related learning for students at the public school and college levels. Other, longer existing programs, such as technology

education and home economics, have begun to integrate both the language and activities of technological literacy into their goals and practices. Professionals from these subjects, in attempting to implement technological literacy programs either as separate or integrated efforts, are faced with the difficulties of how to select, design, develop, and provide specific learning experiences that deliver technological literacy. Lacking a clear vision of what constitutes the major elements of technological literacy, and how these elements relate to each other, developing programs that achieve the desired goals of technological literacy is a chancy business at best.

CONTEXT OF TECHNOLOGICAL LITERACY

As indicated earlier, many of the problems encountered in the professional discussions about technological literacy stem from the various levels of meaning ascribed to technology. The use of multiple meanings of technology and technological literacy should not be seen as an excuse for imprecision in how our profession uses these terms. Rather, the nuances of meaning that can be assigned to a term should allow for more precise treatment of the ideas and phenomena related to that term. For a useful example, consider the many different definitions and meanings that Eskimos give to what we generally call snow. Because snow is of such importance to the Eskimos, it is necessary for them to make fine discriminations far beyond those we would normally make. Indeed, in our naiveté, we would simply see **snow**. A similar naiveté on the part of the Eskimos regarding this important aspect of their environment could result in problems, catastrophe, and even death.

Technology is a complex term and it requires, even deserves, multiple meanings. The point voiced by Bjorkquist & Swanson (1981) that there is no single definition of technology states the obvious. Few words have single meanings. The multiple meanings of technology are not the issue. Many in the profession use more than one definition and slide in and out of the different meanings with relative ease while maintaining acceptable levels of common understanding. Our concern should quicken, however, if the definitions that we use for technology are significantly different, one from the other, or if our profession's definitions are significantly different from those of other professions.

Definitions are constructed from smaller and/or less inclusive terms which can be considered as components. The definitions that we use

would be built from selected key components. For example, one might decide that technology involves **problem solving** or **applied knowledge** or both. If these are seen as basic components of a working definition, then all definitions that we use, at whatever level of sophistication, would include or be compatible with problem solving and/or applied knowledge. Once selected, key components should be maintained to insure consistency in the use of the term.

Literacy as a Component of Technological Literacy

Although **literacy** represents a major component of the technological literacy concept, it remains loosely defined and ambiguous. This ambiguity creates a serious problem for the community of professionals who attempt to chart the unfamiliar domain of technological literacy. Too often these professionals are new immigrants to a land and language they do not understand. As a new immigrant, it is easy to lose one's way, difficult to communicate with other professionals, and impossible to extend the work of the profession.

Considerable attention has been given elsewhere to the meaning, nature, and characteristics of literacy, as reviewed by Dyrenfurth (1984). Just as technology has a range of potential meanings, so too does literacy. A restricted meaning of literacy refers to the ability to read and write. Perhaps the most comprehensive meaning of literacy is equated with being "educated." Notably, the term literacy is not what it seems—or what it used to be.

Literacy has evolved in subtle ways. It has come to be closely linked with **liberal education**. Such linking is not all bad, since it suggests that even the liberally educated should understand something about science and technology. The proliferation of Science/Technology/Society courses in liberal arts colleges attests to the growth of this idea and the power of the thought behind it. For example, Stephen White (1986, p. 7) stated in the foreword of a Sloan Foundation document: "to believe, in this era, that a man possesses a liberal education who is ignorant of analytical skills and technological skills is to make a mockery of the central concept of liberal education and to ignore the nature of the world in which the graduate will live, and to which he hopes to contribute in one way or another."

Technology as a Component of Technological Literacy

What different writers consider to be technological literacy is very much influenced by what they see as technology. The concept of tech-

nological literacy proposed by those with engineering backgrounds looks unsurprisingly like engineering. Since engineers tend to engage in the analysis of systems and artifacts, an understanding of technology would require an understanding of these forms. Systems analysis would include modeling, predicting, probability assessment, simulation, optimization, and risk analysis. Artifacts include the structures and machines of technology. The treatment of artifacts requires the teaching of basic principles of how a device works, and its capabilities and limitations. Additionally, historical development should be considered: the scientific, technological, and cultural settings from which the device evolved, and the assessment of its impacts, both positive and negative.

Technological literacy, as described by those from a design background, would place importance on different activities and understandings. More attention would be given to the aesthetic aspects of artifacts and the major problem solving activities would encompass more than the systems analysis approach proposed by engineers. The quandary faced by those who would strive to help students become technologically literate is not to choose one perspective of technological literacy over another but to determine the commonalities that extend across them all.

MYTHS AND MISCONCEPTIONS OF TECHNOLOGICAL LITERACY

Time and space do not permit a detailed consideration of all the myths and misconceptions of technological literacy. Rather, it will be more productive to consider some of the major aspects of this dilemma. Three dimensions to this problem are considered here. These are presented as the conflicts between **knowledge versus ability**, the differences of **technological understanding versus action** and the perspective of the **disciplinary versus interdisciplinary** study of technology.

Knowledge Versus Ability

One conflict that emerges when implementing and expanding technological literacy offerings arises from the different values placed on technological knowledge versus ability. There are far more teachers who are comfortable in engaging students in **talking about technology** than those who can actually engage students in **doing technology**.

Doing technology involves applying what students know about technology to real and practical problems. Consequently it is far easier to find courses that are oriented to talking rather than to doing. Since there are fewer teachers who feel comfortable with their skills related to technology, and especially who can help novice students engage in the direct application of knowledge to solve real problems, it is unlikely that there will be a significant, or at least an immediate, increase of such practically-oriented courses for technologically inexperienced students.

Understanding Versus Action

The second dimension of myth and misconception arises in the conflict of whether an understanding of technology is enough or if that understanding must be translated into some form of action. Some teachers would be quite happy if their students achieved a satisfactory level of understanding of technology. In fact, technology as a discipline or a school subject suggests that there is something important to know about technology. Teaching technology could be compared to the teaching of history, science, mathematics, or other subjects. Little concern might be given to what the students will do with the knowledge they have acquired.

For many others in technology education, however, understanding is important but insufficient. Understanding is in essence only the first of several desired competencies. Also of major importance is what students are going to do with their understandings. But, even when stressing use, considerable diversity may still exist. Some teachers may be satisfied with the students' ability to use what they learned in fabricating artifacts. Others will want students to engage in the designing, constructing, and improving of those artifacts. Some will be concerned that the specific skills that the students have learned will be useful in helping them become better decision makers related to technology, careers, and beyond. And others will want students to transfer what they have learned to new and unfamiliar instances.

Disciplinary Versus Interdisciplinary Perspectives

The third dimension of concern is the overriding tendency, in technology-related studies, to turn to specialization. The amount of information and the array of skills that are to be learned and developed tends to encourage individuals to become specialists in a chosen field. The point to consider is that individuals can become so specialized that

it detracts from their own technological literacy. For example, one could specialize in electronics as an important area of study. Many become envious of individuals who have steeped themselves in the knowledge and technique of such a complex area of study. It is unfortunate, however, if such specialization takes place at the expense of being able to transfer that knowledge to other areas of work.

Transfer will continue to become more important as the possibility for in-depth understanding in several areas becomes more difficult. For example, a specialist could be unaware that the concepts and formulas used in electronics can be applied in mechanics, pneumatics, hydraulics, and optics. It is unfortunate if individuals are not able to see that the knowledge they have gained can be transferred and applied in other areas of work.

Teachers who do not see the interdependence of knowledge and the interdisciplinary nature of technology concepts will be ill prepared to help students transfer what they have learned to new and/or different circumstances. Similarly, but at a different level, the underlying conceptual models of electronics (or other energy and information conversion methods, for that matter) can provide insights into how larger systems operate and how they can be controlled. In essence, a lot of knowledge can be learned and transferred to new and unfamiliar instances by the truly literate person.

Evolution of Scientific Literacy

The development of technological literacy has been significantly influenced by an earlier concern for scientific literacy. Scientific literacy, in turn, emerged largely in quick response to the embarrassment of Sputnik, more than three decades ago. The major concern was **science for effective citizenship**. This fell within the conceptual boundaries and the battle cry of scientific literacy. Although some writers had kindled the fires of attention to the problem prior to Sputnik (Clem, 1950; Bailey, 1957) the real fanning of the flames took place in the writings that came after that nationally embarrassing event (Hurd, 1958; Behnke, 1960; Ubel, 1961; Evans, 1962; Johnson, 1962; Carlton, 1963; and Shamos, 1963). Drawing on these works and the work of many others, Pella, O'Hearn, & Gayle (1966) attempted to determine the referents of scientific literacy. Based upon the analysis of a broad array of what others were saying about science education, they proposed that:

The scientifically literate individual presently is characterized as one with an understanding of the (a) basic concepts in science, (b) nature of science, (c) ethics that control the scientist in his work, (d) interrelationships of science and society, (e) interrelationships of science and the humanities, and (f) differences between science and technology (p. 206).

The relative lack of emphasis placed on technology as well as the humanities and conceptual learning was identified in the following interpretations made by Pella and his colleagues (1966):

Evidence from analysis of the literature concerned with scientific literacy reveals that knowledge of the (a) interrelationships of science and society, (b) ethics of science, (c) nature of science are more important than (d) conceptual knowledge, (e) differences between science and technology, and (f) relationships between science and the humanities (p. 206).

By the 1980's, however, the importance of technology as a component of scientific literacy had changed, as evidenced in the position statement unanimously adopted by the Board of Directors of the National Science Teachers Association (NSTA) in 1982. The NSTA position identifies technology in a far more central role as indicated in their statement that the scientifically and technologically literate person:

- uses science concepts, process skills, and values in making responsible everyday decisions;
- understands how society influences science and technology as well as how science and technology influence society;
- understands that society controls science and technology through the allocation of resources;
- recognizes the limitations as well as the usefulness of science and technology in advancing human welfare;
- distinguishes between scientific evidence and personal opinion;
- recognizes the origin of science and understands that scientific knowledge is tentative and subject to change as evidence accumulates;
- understands the applications of technology and the decisions entailed in the use of technology;

- has a richer and more exciting view of the world as a result of science education; and
- knows reliable sources of scientific and technological information and uses these sources in the process of decision making.

In retrospect, there was some concern about just how much was achieved in the push for scientific literacy in light of the considerable funds that were committed to the cause. Haberer (1986) suggested that the commitment to catch up and regain primacy in scientific and technological superiority was of major concern. Scientific literacy, he pointed out, just came along for the ride, so to speak.

The main purpose of that effort was...political: To locate, to channel the scientific/technical brain-power and expertise towards the articulated ends. Raising the general level of scientific literacy among citizens was...a secondary and, for the most part, a quite peripheral part of that response. Moreover, the program's intent to develop a broader citizen appreciation of science, probably lay in the recognition, that in the long run, support for the large scientific/technological undertakings was based on public opinion. This earlier multifaceted campaign succeeded brilliantly in its key objective...and failed in the larger, cultural goal of creating a broad-based scientific/technological literacy (p. 225).

Evolution of Technological Literacy

The development of technology education and technological literacy has been an ongoing evolutionary, rather than revolutionary, process. The first document in this country that included technology as a potential part of the school curriculum and hinted at technological literacy took shape in 1946 and 1947 under the leadership of William E. Warner (1953). The document, *A Curriculum to Reflect Technology* (1965), was developed for presentation at the first meeting of the American Industrial Arts Association following World War II. The ideas and philosophy behind this document were major influences on the thinking of those who would attempt first to give technology education, and later technological literacy, both meaning and utility.

The work of Delmar W. Olson, especially his book *Industrial Arts and Technology* (1963), can be seen as initiating the next generation of ideas concerning technology as a subject to be learned. Olson was the first to grapple with the difficult problem of identifying the new content structure of industrial arts if it were, indeed, to reflect technology. Most of

the writers who followed, many of them students of Olson and Warner, would pursue this same direction and this work would culminate in the form of the *Jackson's Mill Industrial Arts Curriculum Theory* (Snyder & Hales, 1981).

The result of that past professional effort is simultaneously one of the major strengths and weaknesses of the conception of technology and technological literacy in the United States. The major emphasis was on what industrial arts would become if it were influenced by technology, not on what technology would be as a new area in the curriculum. Consequently there was little success in breaking out of the historical mold or conceptual paradigm that dominated the thinking of the profession. The potential of technology as a radical paradigm was never realized. Consequently there was little success in identifying what technological literacy might be as a new mission of schooling. This lack of success resided largely in the reluctance of the profession to set aside industry as the primary source of curricular content.

Development of Technological Literacy Internationally²

In retrospect, the lack of progress and success in implementing technology education programs that included a commitment to technological literacy was due, in part, to a lack of awareness that innovative technology programs existed outside North America. Consider, for example, the documentation in *Innovative Programs in Industrial Education* (Cochran, 1970). This book served as the major reference when others in the profession discussed curricular change and innovation. Cochran chose not to include programs that were innovative enough to move beyond the conventional boundaries of industrial education. It was also unfortunate that he did not include innovative programs from overseas. But, the fault of parochial thinking must be laid at many doorsteps. Few in this country were aware of the changes that were taking place internationally in technology education and consequently little attention was given to these innovations and what they might mean for technology education or technological literacy efforts in the U.S.

The lack of international communication and cooperation at these seminal times was indeed unfortunate. The paradigms that continued to influence the basic thinking in the United States, England and other

²Eds. note. For purposes of yearbook cohesiveness, the bulk of Todd's extensive insights into the international developments related to technological literacy were incorporated into Scarborough's chapter (3).

countries were significantly different and could have been strengthened through cross-pollination. Individually, the different approaches, although interesting and often productive, were usually inadequate. In retrospect, it appears that an early sharing of the different approaches could have resulted in far more powerful models and paradigms of technology education and technological literacy for all.

The models and paradigms that influenced one country were often different than those that influenced another. Not surprisingly then, different countries tended to view technology differently and defined technology education and technological literacy in unique ways. There are obvious limits to what the concept of technology can mean and some commonality in meaning can be identified. In an earlier work, Todd (1985) proposed that technology, as part of the school curriculum, takes six forms ranging from the specific and instrumental nature of technology to its more general or influential nature (see Figure 1-2). The instrumental nature deals with how technology can be used in a direct manner to create intended changes in materials, processes, and the environment. The influential nature deals with more indirect ways that technology creates unintended changes, particularly in the environment. The six forms include:

- Technology as skills particularly with emphasis on tool skills;
- Technology as a form of motivation that uses hands-on and project activities to add interest to other subjects;
- Technology as a subject in its own right with separately scheduled courses;
- Technology as an end-in-itself that provides conceptual frameworks for integrating content and skills learned in other subjects;
- Technology as a guiding theme that provides organizers for what is included in the curriculum and what students are to learn; and
- Technology as a philosophical perspective that includes a set of higher-level problem-solving skills.

Fortunately the international sharing of experience and knowledge regarding technology education is now accelerating. There is also a tremendous willingness to share experience and knowledge with others. This willingness to share has been rediscovered by a growing number of the technology professionals in this country over the past few years through their contacts with other professionals in England, Denmark, Germany, Australia, Japan, Thailand, Puerto Rico, and the Netherlands to mention only a few.

- Attitudes of students toward technology, as a basis for curricular planning, differ based on sex and based upon their home country.
- And finally, the "basic skills" of technology are emerging as different than those of industrially-based programs. For example, mechanical drawing (as it has been taught), appears to hamper a student's ability to communicate ideas on paper.

TECHNOLOGICAL LITERACY: CHALLENGES AND PROMISES FOR THE PROFESSION

One of the major challenges that resides in the technological literacy movement is the danger of acceptance of technological literacy by the profession and the lay public as an adequate rather than a minimum level of competence. Technological literacy could well become a capstone to progress if it is not seen as a part of a larger picture. Examining the term in a larger context of meaning can illustrate that **literacy** is only one of the goals for a technologically responsible populace. In the taxonomy of "capability of technological decision-making" presented in Figure 1-3, five terms are proposed to clarify the position of technological literacy in a larger context.

LEVELS	TYPES OF KNOWLEDGE	COMPETENCE
I TECHNOLOGICAL AWARENESS	KNOWLEDGE THAT	UNDERSTANDING
II TECHNOLOGICAL LITERACY	KNOWLEDGE THAT	COMPREHENSION
III TECHNOLOGICAL ABILITY	KNOWLEDGE THAT & HOW	APPLICATION
IV TECHNOLOGICAL CREATIVITY	KNOWLEDGE THAT & HOW	INVENTION
V TECHNOLOGICAL CRITICISM	KNOWLEDGE THAT, HOW & WHY	JUDGEMENT

Figure 1-3. A taxonomy of capability for technological decision-making.

The taxonomy embraces five levels of technological capability: Awareness, literacy, ability, creativity, and criticism. As a corollary to these five levels there are five levels of competence: Understanding,

comprehension, application, invention, and judgement. The first two levels deal primarily with what Gilbert Ryle has described as **knowledge that**. Levels three and four reflect Ryle's notion of **knowledge how** (Ryle, 1949).

The fifth level emphasizes a more comprehensive **knowledge why**. This hierarchy of competencies represents the technological capability of an individual skilled in making technologically related decisions. Within this framework **literacy** falls short of an ultimate goal of technological capability that includes creativity and criticism and their corollary competences of technological invention and judgement.

Knowledge in Practice Through Technological Literacy and Technological Capability

To understand some of the potential power of technology as an integrator and generator of knowledge, a few vignettes of practice in teaching technology may be helpful. Consider, for example, the richness of learning experiences that reside in the combining of drama, writing, and technology classes to have the students interpret and stage existing plays as preparation for moving on to creating, designing, and producing their own plays. The inclusion of technology, not only for building the stage settings, but also for the lighting, control, and video recording of the play introduces new opportunities for integrating what the students are learning and for applying what they know to new and unfamiliar circumstances.

Other examples could include: Pollution studies of the school, home, and community by merging biology, psychology, and technology; museum or science/technology exhibits that bring together classes in science, technology, history, and art; local archeology projects that draw upon science, mathematics, history, and technology; community service projects that apply what students have learned in art, psychology, social sciences, and technology. Obviously, the list of activities that can contribute to both technological literacy and capability could go on and on. These practices emerge from an integrative perspective that considers technology as the application of knowledge to purposeful or practical ends. Within this context, teachers can work with students in applying technology as a means to use and direct the knowledge from other fields, as well as the knowledge from technology, to solve practical problems in order to accomplish desired ends and goals.

The integration and generation of knowledge through technological activities has exciting and untapped potential for enhancing technologi-

cal literacy and technological capability. Part of that power resides in using and teaching technology cooperatively in the classrooms and laboratories of our colleagues from other disciplines. Teaching technology on their grounds, within their context, and for their purposes can create new insights about technological literacy and technological capability and about what we think is important to know about technology. Such interdisciplinary approaches can also use the work of students as personal instances of realism for considering the consequences and impacts of technology activities. These contexts of integrated learning can help achieve and enhance the technological literacy of our students while also laying the foundation for students to move to higher levels of technological capacity.

In order for us to capture the potential of technology for integration and application of learning and knowledge, it will be essential for teachers and students to learn new educational behaviors. It will no longer be appropriate to think about teachers only as teachers and students only as students. The lines between teaching and learning will continue to blur, especially as computers and other media-technology devices become more available in the classroom and laboratories. We can already see technologically capable students becoming teachers and teachers becoming students. For most who have experienced that role reversal, it has been very exciting, particularly as students begin to experience some of the rewards of teaching and as both students and teachers begin to experience some of the delight of cooperative learning.

Technological Literacy: A New Education Mandate

There is a great deal of power for change residing in technology education and technological literacy. There are several efforts emerging to implement technology as a content area within the school curriculum. These efforts could establish very important symbiotic relationships or they could create competitive and nonproductive relationships. Each of these efforts have something to add to the overall experience for students. Each, however, is inadequate to the educational task that lies ahead. There are major obstacles to overcome if we are to see technology included as an important, even essential, part of the curriculum. Educational innovation and change is not for the fainthearted nor for the loner, whether an individual or association.

In essence, the totality of our efforts could be more than the sum of our individual contributions. Such a synergy is possible if ways are found to integrate, and consequently maximize, the work of those involved. For example, many of the programs and their participants feel very comfortable when engaging students in important and interesting discussions about technology and its impacts. Others place more importance, or are more comfortable, in engaging students in the direct use and study of technology. Others yet have found it more productive to have students engage in problem-solving activities that reflect a design process of how one goes about finding the best possible solution to a problem. Even others see technology as the media through which new content and skills can be taught in a wide range of subjects. Imagine how vital the learning would become for students if they could experience all these variations of technology throughout the curriculum!

The results and effects of the above would shake education to its foundation. The introduction of the practical aspects of learning, in all their richness, through the study of technology and the pursuit of technological literacy and capability, would radically change what goes on in the schools and how teachers and students interact. The cry for relevance, meaning, and engagement in learning would finally be answered. It is to these potentials, these ends, these changes that our efforts must be directed.

CHAPTER TWO

EDUCATION ABOUT TECHNOLOGY

by

Michael R. Kozak and Janet Robb¹

If we compress all of the 15 billion years of the evolution of the universe as we know it into a single 24-hour day, the Big Bang is over in less than a ten billionth of a second. Stable atoms form in about four seconds; but not for several hours, until early dawn, do stars and galaxies form. Our own solar system must wait for early evening, around 6 p.m. Life on earth begins around 8 p.m.; the first vertebrates crawl onto land at about 10:30 at night. Dinosaurs roam from 11:35 p.m. until four minutes to midnight. Our ancestors first walk upright with ten seconds to go. The Industrial Revolution and all our modern age occupy less than the last thousandth of a second. Yet, in this fraction of time, the face of this planet has been changed almost as much as in all the aeons before (Myers, 1984, p. 14).

Exactly how are people changing this planet? In one day, Americans: (a) use 450 billion gallons of water, (b) produce 500,000 car and truck tires while spending \$250,000 to get rid of the old ones, (c) lay about 3,000 acres of pavement, (d) produce over 60 million newspapers on 23,000 tons of paper, (e) use 57 billion kilowatt hours of energy, and (f) add 150,000 miles to the telephone network (Parker, 1985).

The escalating impact of technology may also be demonstrated by considering the effect of a single technological event. For example, consider how one of the Hiroshima survivors would describe the impact of that **single** event in the history of technology.

¹Michael R. Kozak is Associate Professor in the Department of Industrial Technology, at the University of North Texas, Denton, Texas. Janet Robb is USAID Design and Technology Consultant in Botswana, Africa, for Florida State University.

THE CHALLENGE OF TECHNOLOGY

Technology is simultaneously the: (a) major component of industrial and economic activity, (b) significant determinant of military capacity, (c) a frequent focus of recreational activities, (d) coveted cornerstone of a desirable future, and (e) fervent hope for the resolution of our pressing problems. Systematic analysis reveals technology as the process of creating, utilizing, and discarding of adaptive means—including tools, materials, processes, energy, and information—and relating these individual elements and/or collective systems to individuals, society, and the environment. While science may provide the facts as they exist, technology feeds on all appropriate knowledge and imagination to provide the know-how of what is possible (DeVore, 1980; Dyrenfurth, 1984).

Rate of Change

American industrial productivity seems to be continuing its steady 15-year decline as one industry after another yields to international competition. Each year in the United States, approximately 10,000 industrial companies close their doors for good. Alienation and isolation in the work place and/or community have often been a result of technological growth or change (Davis, 1980).

Knowledge and skills that have provided employment for a generation or longer are being made useless by exponential technological growth and are being replaced with new jobs that require new knowledge and new skills.

In the computer industry, for example, William C. Norris (Naisbitt, 1982), then the Chief Executive Officer of Control Data Corporation, projected a job growth during the 80's of 147 percent for computer maintenance technicians and 107 percent growth for computer systems analysts in his industry alone. Innovations will continue to make obsolete that which is commonplace in today's industrial environment.

Meta-technology can better explain the massive underemployment factor. Meta-technology is the concept that, as one innovation or improvement occurs, it generates a ripple effect with implications for other aspects of industry, which in turn, affects still more areas of technological productivity. Massive unemployment accompanies these innovations, usually because, in reality, industry exists to make a profit, not to provide employment.

Technology has existed since the first human began to seek control over the environment. The manipulation of stone, bone, hide, and metal led to an ever increasing range of applications. Thus began the exponential growth of technology, a growth that continues at an ever-increasing rate. Naisbitt (1982) reported that, at the time of his research, technological knowledge doubled every 5.5 years. One can count on even faster progress today.

The exponential growth of technology affects all of society: communication, transportation, construction, and production. Electron-beam lithography, a communication process, is so precise it has been used to reproduce the entire *Encyclopedia Britannica* on a postage stamp. With the development of an appropriate reader, imagine the future capacity of home libraries.

Electronically enhanced infrared scopes are used to see at night. Giant telescopes and photographic emulsions are used to see into the depths of space. Radio telescopes can see to the center of the galaxy. Computer tomography and magnetic resonance imaging are used to look inside the human body. Communication technology is also pushing marvelous new frontiers, for example, the theoretical limit of today's optical fiber system is 100,000 simultaneous conversations (Perreault & Kozak, 1984).

Southern Californians make 50 million daily vehicle trips, and this is expected to rise to at least 65 million by the year 2000. Japan's magnetically levitated train may be an example of alternative futuristic terrestrial transportation. The vehicle is projected to operate at speeds over 300 miles per hour due to the use of superconductors for levitation (Perreault & Kozak, 1984).

The construction market is being impacted by new materials such as advanced polymer composites, techniques, and robotics. Modular construction, if globally accepted, will eliminate many of the common and wasteful techniques used today.

Although many additional examples may be used to demonstrate the exponential growth of technology, perhaps the rate of change is best demonstrated by citing one particular example in greater detail: composites. A composite material is a complex primary structural form that combines two or more materials to provide a desired property superior to the properties of either of the individual materials. The components of a composite do not dissolve or merge together. Instead, they act in concert (Composite materials, 1986).

Worldwide sales of advanced composites are expected to grow 15 percent annually into the next century with shipments valued above \$10 billion annually). This rate of change to a new material form has also resulted in new production processes that did not exist only a few years ago: (a) reinforced reaction injection molding, (b) resin transfer molding, (c) bag molding processing, (d) automated tape laying, (e) pultrusion, and (f) filament winding. New processes are being used for new materials that are specifically designed for almost each new product.

The point is that the meta-technological effect, based on an exponential rate-of-change, produces rampant change in a variety of industries, in a variety of employment opportunities, in a variety of daily activities. Given this effect, one can only wonder what life will be like 50 years from now. Will the United States continue its comparative downward technological spiral? The U.S. has lost 20 percent of the automobile market to Japan, 33 percent of the camera market and over 50 percent of the radio market. Will this continue? The U.S.S.R. has demonstrated the ability to haul 100 tons into space compared to the obsolete U.S. Saturn which could only haul 50 tons. The U.S.S.R. launches almost 90 percent of the world's payload and has made a significant bid for the exploration of Mars (Lauda, 1987). Will the U.S. role in space exploration also decrease?

The fourth wave, which is projected to last until approximately 2045, will be based on artificial intelligence and the application of thought to electronic technology. Will the United States be a participant or an observer (Raymond, 1986)?

Society's Utilization of Technology

Americans live in an electromechanical, digital, computational, chemical, biomedical society. Humans use technology to provide society with new capabilities and new opportunities. Technology makes obsolete certain ways of life and certain values. Technology in today's society is centralized, specialized, autocratic, threatening, and intimidating. For example, the increased use of robots that can serve and service machines and other robots may substantially increase the unemployment rolls and perhaps even increase the number of individuals on welfare. In some plants, when the first robot arrives, the workers know their time of employment is limited. It is only a matter of time till they are replaced. Anxiety sets in. Quality and productivity suffer.

Women, through the use of work-reducing devices in the home, have used technology to redefine their role in society. Technology, through contraceptives, has separated the sexual act from procreation, making the family unit only one method of ordering and obtaining such gratification in society. Technology is rapidly changing the typical family home. Technology also affects homelife by providing some with increasing leisure time and also providing contemporary activities and equipment to occupy that time.

Religious pilgrimage has been made available to more people in contemporary society because of technology's impact on transportation. The television evangelist is also an integral aspect of today's technological society. Technology has had a direct impact on society's participation in politics. Not only does television provide visual contact with politicians, but governmental control of the medium could result in control of society itself.

The technologies of medicine offer great promise for society. The chance of survival of a newborn infant to late middle age has greatly increased over what it was at the turn of the century. However, the question may become, should this opportunity be extended to newborns who carry genetic defects? Who should decide (Pytlik, Lauda & Johnson, 1985)?

Economists state that the rate at which money changes hands in a society influences expenditure, thereby affecting the money supply. Technology, through high-speed computers and telecommunication systems in multinational banking institutions, has added tremendous impact to this increasing spiral thus creating a fake increase in the actual money supply which causes prices to rise, thereby decreasing the value of the dollar on the world market (Pytlik et al., 1985).

Whereas the diminishing industrial society of the past was based on electricity, the post-industrial age is based on electronics, computers, lasers, CAD/CAM/CIM, and other technological systems that stretch the imagination and our capability. Also referred to as the information age, the thrust towards a post-industrial society will be built on efficiency, conservation, quality, and flexibility. Quantity, the prime mover of the industrial age, may shortly be forgotten.

Understanding Technology

Technology can be defined as the systems and objects or artifacts that are created using knowledge from the physical and social spheres

of activity. These systems and artifacts are typically designed to have a purpose which affects the activities and organization of society. Technology is part of a process which we do to modify the environment in response to human needs (Friedman, 1980).

Is it becoming necessary for all people to understand technology if they are to function as citizens? A Harris (1970) poll defined literacy as: "... the ability to respond to practical tasks of daily life" (p. 10). Anyone who understands technology is able to apply knowledge and also able to perform tests using tools, machines, materials, equipment, and processes that result from advancing technology. However, given the exponential growth of technology, the varied purposes of education, and individual perspectives, not all persons need to understand technology to the same degree.

Modern technological solutions seem to create a sense of uneasiness or a sense of frustration that early technological knowledge did not. This attitude of dread and rejection has drastic effects on the acquisition of technological knowledge. If people are disheartened by something, they typically do not learn about it; they definitely do not attempt to become literate about it (Brockway, 1987).

Technology is a body of knowledge and capabilities that is distinct from others. Often it precedes, rather than follows, scientific understanding (Brockway, 1987). Because of a mistaken tendency to equate technology with computers, a caveat is in order. Advocates of computer literacy must learn their pets' (computers) rightful place in a technological society. Computers are but one segment of the world of technology; technology is not a part of computing. Given this relationship, the concept of technology contains computer literacy (Dyrenfurth, 1984).

THE CHALLENGE FOR EDUCATION

Man has before him the possibility of a new level of greatness, a new realization of human dignity and effectiveness. The instrument which will realize this possibility is that kind of education which frees the mind and enables it to contribute to a full and worthy life. To achieve this goal is the high hope of the nation and the central challenge to its schools (Educational Policies Commission, 1961, p. 21).

One of the fundamental truths of this new age of technology is that it is not possible to select, design, operate appropriately, or control technical systems without a thorough knowledge and understanding of the behavior of the systems and their relation to human beings, their society, and the environment. The design and operation of the new technical means required for our transfer to a sustainable and preferable future mandates a highly educated populace (DeVore, 1987, p. 70).

The challenge for education is real, and currently the successes are questionable. Seventy-five percent of high school youth never graduate from college, and over 3,000 students drop out of high school each day in the United States (Thomas, 1987). Forty percent of the students leaving high school cannot read beyond the ninth grade level (Lauda, 1987). More than 30 recently issued reports prepared by task forces, commissions, and individuals demand that urgent attention be given to American schools (Thomas, 1987).

Purposes of American Schools

The American people have traditionally regarded education as a means for improving themselves and their society. The Commission on the Reorganization of Secondary Education proposed, in 1918, a set of seven cardinal objectives for the school: (a) health, (b) command of fundamental processes, (c) worthy home membership, (d) vocational competence, (e) effective citizenship, (f) worthy use of leisure, and (g) ethical character. The Educational Policies Commission developed, in 1938, a number of objectives for the school under four major headings: (a) self-realization, (b) human relationships, (c) economic efficiency, and (d) civic responsibility. Fifty years later, these purposes of education are still appropriate (Educational Policies Commission, 1961).

Domains of Learning

Educational psychologists categorize learning into three domains: cognitive (knowing), affective (feeling), and psychomotor (doing) (see Figure 2-1). Shemick (1985) lists the appropriate levels within each domain. Education programs must permit every student to experience learning in all domains and at all levels if learning is to be meaningful.

Level	Cognitive	Affective	Psychomotor
1	Recognition/Recall	Receive	Observing
2	Comprehension/Interpretation	Respond	Imitating
3	Application	Observe/Value	Manipulating
4	Analysis/Synthesis	Organize	Performing
5	Evaluation	Characterize	Perfecting

Figure 2-1. Domains of learning.

The Ability to Think

The traditionally accepted obligation of the school to teach the fundamental processes developed by the Commissions in 1918 and 1938, is clearly directed toward the development of the ability to think. The central purpose of the school, which runs through and strengthens all other educational purposes and is the common thread of education, is therefore the development of the ability to think. A person who thinks can understand the importance of the ability to do so. It is the thinking person who can bring all valid purposes into an integrated whole. Rationality is a means as well as an end (Educational Policies Commission, 1961).

Education must be infused with the process of thinking and the attitude of thoughtfulness. Choice as to methods and means of developing the ability to think is in the hands of the individual instructor. It is crucial, therefore, that the instructor possess a thorough knowledge of the material to be taught, mature mastery of a variety of teaching procedures, an understanding of students, and the quality of judgement to blend all in making decisions (Educational Policies Commission, 1961).

EDUCATION ABOUT TECHNOLOGY

Technological knowledge is one of the primary hallmarks of the American culture. If knowledge is power, then those with technological knowledge will hold the power of the future (Brockway, 1987).

Technology education, as a name for a program area of study, evolved from discussion (circa 1970) between Dr. James Harlow,

President of West Virginia University and Dr. Paul DeVore. It also was the title given to a curriculum area designed to teach about our technological past, present, and future. Since that time, the term **technology education** has been increasingly accepted and used.

Recent Historical Developments and Influences

A variety of events has served to promote the understanding and acceptance of technology education as a necessary component of a formal education. In 1972 Paul DeVore made a major contribution to this effort in his work "Education in Technological Society." Eastern Illinois University, in 1976, established the first undergraduate degree in technology education under the leadership of Donald P. Lauda. Since beginning in 1980, more than ten symposia and six national technological literacy conferences focusing on issues related to technology education have been held throughout the country.

The acceptance of any educational program, however, depends upon the successful development of appropriate goals, objectives, rationale, philosophy, curriculum, and methodology. One of the most significant events was the development of a comprehensive philosophy and rationale for the study of technology as a result of the Jackson's Mill Industrial Arts Curriculum Project in 1981. The curriculum model that resulted from Jackson's Mill gives validity and direction to the selection of content to be studied within a curriculum area titled technology education. The intent is that content should be derived from the universal technical systems of communication, transportation, construction, and manufacturing (Snyder & Hales, 1981).

A number of curriculum projects with a focus on technology followed Jackson's Mill and each made unique and significant contributions. To name but a few: Occupational and Practical Arts Futuring Project, New York State Education Department (1981); Industry and Technology Education Project, Technical Foundation of America (1982); and The Illinois Plan (1984). In 1984, the American Industrial Arts Association published their Professional Improvement Plan with goals and directives toward 1986 and a commitment for a change toward technology education. In 1985, the American Industrial Arts Association changed its name to the International Technology Education Association. The First World Assembly on Technology

Education, in 1988, at Norfolk, Virginia, had sixteen countries participating. The fifth PATT (Pupils' Attitude Toward Technology) Conference will be held in 1991 at Eindhoven, Netherlands. This weeklong conference has presentations delivered by individuals from throughout the world including eastern block countries.

All of these efforts reinforce the progress that has been made at local, state, national, and international levels toward the development and implementation of technology education. Historians will tout technology education as one of the disciplines that provided the initial thrust for the integration of knowledge (Lauda, 1987).

Technology Education in the Public Schools

Approximately 60 percent of the states are engaged in curriculum work to upgrade technology education programs (Jones & Wright, 1987). If properly taught, most public school subjects, including technology education, can help the student to:

- know and appreciate the importance of technology;
- uncover and develop individual talents;
- apply problem-solving techniques;
- apply other school subjects;
- apply creative abilities;
- deal with forces that influence the future;
- adjust to the changing environment; and
- make informed career choices (ITEA, 1985).

However, technology education, in particular, develops the students' capability to:

- apply tools, materials, processes, and technical concepts safely and efficiently; and
- become a wiser consumer (ITEA, 1985).

Figure 2-2 is a model for the curriculum structure of technology education at the three levels of public school education: elementary school, middle school, and high school. Technology education is a fundamental and basic area of study suitable for all students at all grade levels. As Maley (1987) stated, "A critical school-based issue is to establish technology education as an educational staple in the diet of all students in our schools." (p. 20)

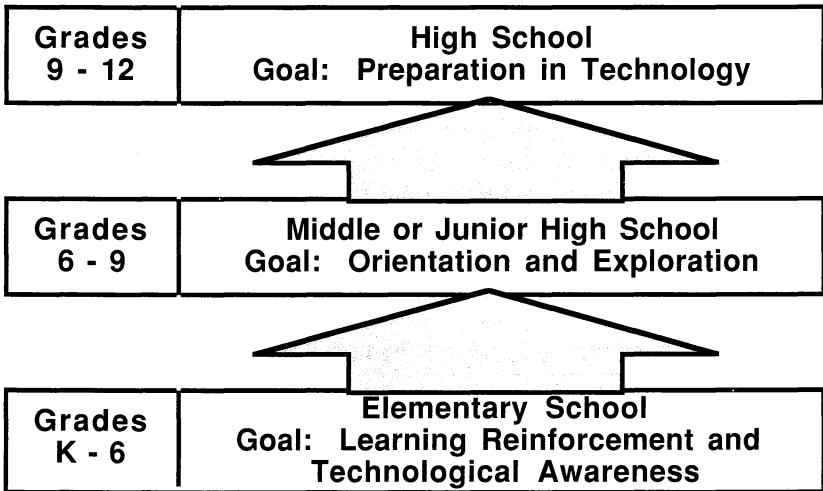


Figure 2-2. Curriculum structure for technology education (ITEA, 1985, p. 25).

Elementary School Technology Education

"The aim of the elementary school technology education program is to develop a first-hand understanding of the technology that supports daily life" (Peterson, 1986, p. 47). In other words, how does technology work and how does it affect people? A technology-based elementary school program prepares students to understand their culture and the culture of others. Technology education at the elementary school level is usually taught by the regular classroom teacher and is incorporated into units dealing with other issues of learning.

Middle School Technology Education

Technology education at the middle school level is exploratory in nature. It is at this level that content is focused around the technological system areas of communication, transportation, manufacturing, and construction. Although typically focused on the four technological areas, the curriculum is broadly presented. It is recommended that all students at the middle school level take technology education (ITEA, 1985).

	6th Grade	7th Grade	8th Grade
Exploratory	<ul style="list-style-type: none"> Recognize wide range of student interests Provide variety, flexibility of materials used & concepts learned 	<ul style="list-style-type: none"> Students explore production, power & transportation & communication systems 	<ul style="list-style-type: none"> Study of variety of materials and the processes of working with them. Humans use materials to improve their life on earth.
Broad & Fundamental	<ul style="list-style-type: none"> Develop understanding that technology is human-created Answer, "What is technology?" Conceptually based 	<ul style="list-style-type: none"> Systems of technology, power & transportation, communication, processing, manufacturing, construction Conceptually-based 	<ul style="list-style-type: none"> Elements of technology operate in certain ways to result in consequences for humans Conceptually-based
Interdisciplinary	<ul style="list-style-type: none"> Study of technology can reinforce learning in social sciences, humanities, natural sciences 	<ul style="list-style-type: none"> Technology-Science-Humanities are interdependent, each contributes and depends upon the other 	<ul style="list-style-type: none"> Science of materials Physics of processes Social impact of technology Consequences of technology
Vertically Integrated	<ul style="list-style-type: none"> Transition from learning reinforcement function of the elementary school study of technology to more narrow specialized study 	<ul style="list-style-type: none"> With basic understanding of the nature of technology acquired in grade 6, study can begin to be more specific The study of technological systems 	<ul style="list-style-type: none"> Increasing specificity Preparation to enter high school curriculum
Understanding	<ul style="list-style-type: none"> Close pupil-teacher contact Begin transition from elementary school Fast-paced, active 	<ul style="list-style-type: none"> Increasing departmentalization Increasing student responsibility Activity oriented-exploration 	<ul style="list-style-type: none"> Begin transition into high school Increasing departmentalization Recognize developing & changing student interests

Figure 2-3. Articulation in industrial /technology-based education in the middle school (Bame, 1986, p. 74).

Grades	Recommended Courses	Type of Course
8-9	Communication Systems Construction Systems Manufacturing Systems Transportation Systems	Elective courses, each a semester in length
6-7	Introduction to Industrial and Technological Systems	Required course, a semester in length

Figure 2-4. Recommended courses in technology education for the middle school or junior high school (ITEA, 1985, p. 26).

According to Bame (1986), a middle school technology education curriculum should be: (a) exploratory, (b) aimed at understanding, (c) broad and fundamental, (d) interdisciplinary, and (e) vertically integrated (see Figure 2-3). Recommended courses in technology education for the middle school level are illustrated in Figure 2-4.

High School Technology Education

The intent of a high school technology education program should be to provide students with a plan of study to help them become knowledgeable and wiser decision makers about the technological environment in which they live.

Technology education at the high school level should include course offerings from each of the systems or sub-systems used to encompass technology. Jackson's Mill-based programs would use communication, construction, manufacturing, and transportation for example. These might include courses in graphic communication, media communication, electronic communication, construction planning and design, constructing and servicing structures, electro/mechanical systems, materials and processes, designing manufacturing processes, production systems, transportation planning and design, and/or transportation systems.

According to the International Technology Education Association's *Technology Education: A Perspective on Implementation* (1985), as a result of technology education at the high school level, students will:

1. experience the practical application of basic scientific and mathematical principles;
2. make decisions regarding postsecondary technology careers, engineering programs, or service-related fields;
3. make decisions with regard to advanced vocational education programs;
4. gain an in-depth understanding and appreciation for technology in our society and culture;
5. develop basic skills in the proper use of tools, machines, materials, and processes; and
6. solve problems involving the tools, machines, materials, processes, products, and services of industry and technology (p. 27).

Technology Education in Colleges and Universities

Technology education courses allow colleges the opportunity to keep a strong foothold in traditional humanities while relating them better

to the world in which we live. Faculty and administrators at Lehigh University have dedicated ten years to the development of the Science, Technology and Society Program which they believe prepares students to live and work in a highly technological society. Recognizing the implications and interactions of science and technology on modern life, the faculty at the Massachusetts Institute of Technology has also established a Program in Science, Technology and Society to provide both engineering and non-engineering majors with a social context from which to view scientific and technological activities and events. St. Louis University administrators and faculty have developed the Man, Technology, and Society Program which they believe helps prepare students for the 21st century. The program provides students with an interdisciplinary understanding of technology's role and influence in American culture.

The Department of Technology and Society (DTS) at the State University of New York (SUNY)—The College at Stony Brook was established as an independent entity in 1978. Any social or philosophical issues that arise from class discussions are considered within the context of technological feasibility. Approximately 75 percent of all SUNY-Stony Brook undergraduates sign up for at least one DTS course. By learning technological skills and proper problem-solving attitudes and procedures in a Patterns of Problem Solving course, students at the University of California, Los Angeles devise solutions for both personal and world problems. The University of Wisconsin—Madison College of Engineering offers seniors and graduate students a Sociotechnical Systems Design Program designed to integrate engineering and technology with liberal arts learning (Friedman, 1980).

Technology Education Teacher Preparation Programs

In the 1950's and 1960's many teacher preparation colleges became state universities with missions that transcended teacher preparation. Throughout the 1970's, enrollments in industrial technology programs increased dramatically while enrollments in technology teacher education declined equally dramatically (Erekson, 1987). With unfortunately few exceptions, technology teacher education programs today are virtually being squeezed out. Some technology teacher education programs are absorbed into industrial technology programs but others are just closed. In addition, students who enter technology education programs often transfer to industrial technology due to the many advantages such as starting salary, employment opportunities, and occupational status (Jones & Wright, 1987).

Maintaining a strong, quality-driven public school technology education program begins with the preparation of competent and caring instructors. However, what are competent instructors? If prospective technology education instructors are prepared for available jobs, then the status quo is perpetuated; if they are prepared for non-traditional programs, such jobs may not be available. The challenge facing teacher educators is to design a technology education program that is future oriented yet provides its graduates with the ability to teach technology education in the existing school environment (Kozak, 1982). If technology teacher educators act responsibly and responsively to educate future generations of instructors, programs will be designed that will meet the needs of tomorrow. Courses that are even questionably irrelevant in 1990 will definitely be so in the future (Seidman & Kozak, 1983).

With the escalating thrust toward technology-based programs at the public school levels, major changes in teacher preparation programs are necessary to prepare instructors who have a comprehensive understanding of the content, organization, philosophy, and methodology of such a program. However, in many instances program changes at the college/university level are lagging behind curriculum changes taking place in the junior and senior high schools. Perhaps at no other time in history has there been a greater need for teacher preparation programs to be pro-active rather than reactive. Strong leadership and direction is extremely crucial in this formative period of school and university program development.

What changes lie ahead? What are some of the predictions for technology teacher education programs? Erikson (1987) predicts that technology instructors will be required to develop competence in mathematics, sciences, computer science, computer applications, economics, labor relations, industrial psychology, sociology, history of technology, and languages. Jones and Wright (1987) predict that regional technology teacher education programs, rather than multiple programs per state, may become a reality. Lauda (1987) indicates that he visualizes teacher education programs in science education and technology education merging into a single entity.

As Maley (1987) points out: "There is a need, as well as a challenge, to educate a new breed of teachers who can deal with the issues related to technology education. This will go beyond the mere capability of teaching craft-related content" (p. 13). According to Henak & Barella (1986), this challenge requires avoiding a common curriculum development mistake—namely that of developing control-oriented, teacher-directed programs.

The 35th Yearbook (Jones & Wright, 1986) provided a study of undergraduate technology teacher preparation in terms of the professional and technical sequence. These authors will also use that breakdown. In fact, it seems most appropriate to summarize that information.

Professional Sequence

The professional sequence of courses in a technology teacher preparation program should provide the opportunity for students in the program to accomplish six things:

- Develop a personal theory. A personal theory provides future teachers a rational basis for their professional activities. Its development hopefully forces a theory that is comprehensive, internally consistent, and individually accurate.
- Use instructional technology. The use of instructional technology refers to the efficient and appropriate practice of teaching.
- Develop a value system. This is essential in a world that is based on technological development. A strong value system will help teachers "view technical progress more in terms of bettering the quality of life than in simply producing something to make a profit" (p. 149).
- Develop a futuristic orientation. This will make it possible for future teachers to consider alternatives and make decisions regarding those alternatives if and when they become reality.
- Become independent lifelong learners. Technology education teachers need to understand the continually changing nature of the curriculum they will be teaching. Along with that understanding is the need to develop ways in which to become continually educated about those changes, their nature, and their ability for impact.
- Develop a positive self-concept. A positive self-image will help a technology education teacher, or any teacher, succeed in the classroom (Henak & Barella, 1986).

Technical Sequence

It is almost impossible for any one person to be knowledgeable in all areas of technology due to its vastness and rapidity of change. Therefore, technology education instructors will have to have a basic understanding of the broad range of technologies. The technical skills of technology education instructors will need to be transferable so they

can be applied in a variety of situations (Thomas, 1987). To achieve this end, elimination of the typical skill development courses needs to be considered. Instead, technology instructors should possibly be required to serve technology-based internships in business and industry. With this de-emphasis on university-centered skill development, the major thrust of the program could be devoted to curriculum understanding, methodology development, and skill transfer ability (Erekson, 1987).

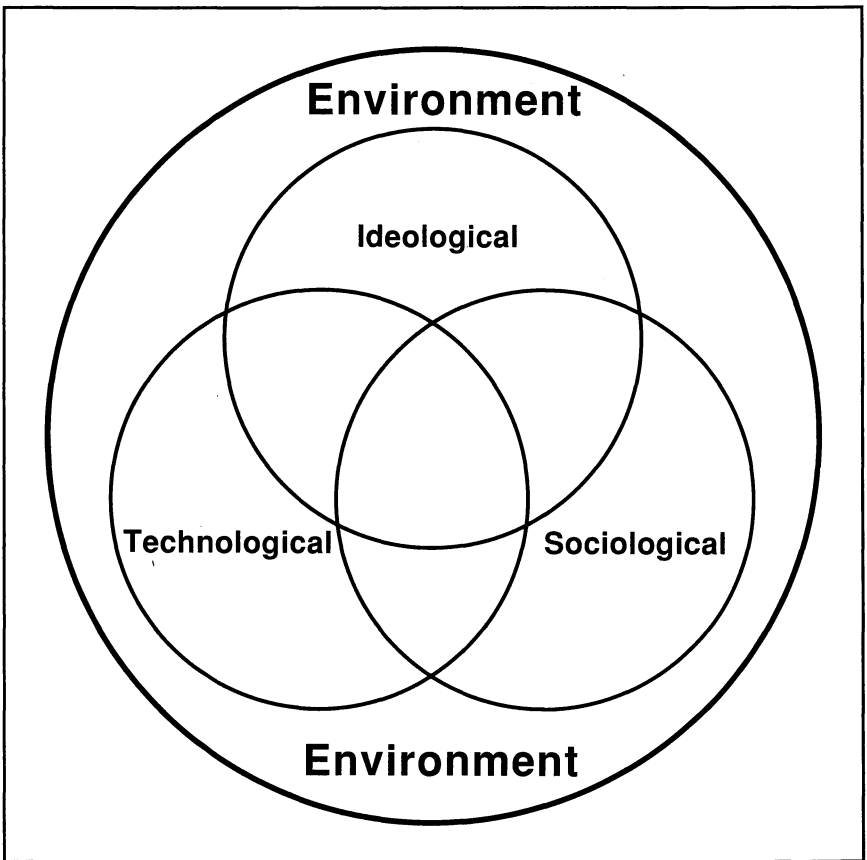


Figure 2-5. The human adaptive systems of ideological, technological, and sociological work together in a human-made and natural environment.

The technical sequence developed for the study of technology education is derived from the human adaptive systems as identified by DeVore (1980) and subsequently the Jackson's Mill Curriculum Project (see Figure 2-5). Within the technological component of the human adaptive systems are the technical means by which we are able to extend the human potential. These technical means can be clustered into the systems of communication, construction, production, and transportation.

Technology education teacher preparation program content is based on the need for future teachers to become technologically literate and, in turn, be able to develop the technological literacy of their students. One overview of a possible curriculum configuration to meet this end may be the scope and sequence model for a four-year technology-based teacher-preparation program indicated in Figure 2-6 (Helsel & Jones, 1986).

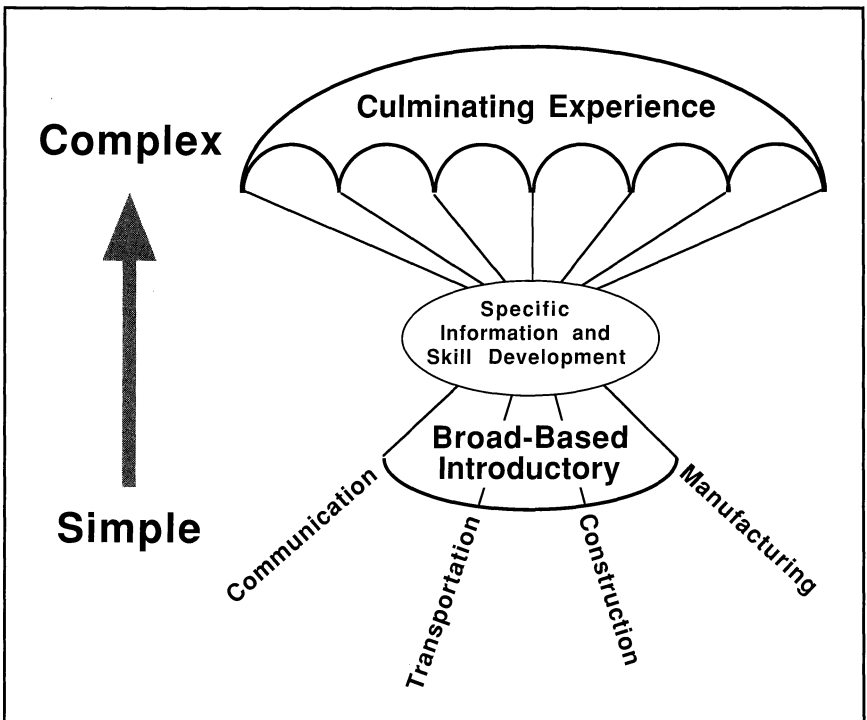


Figure 2-6. Scope and sequence model (Helsel & Jones, 1986, p. 175).

Deriving a curriculum sequence from this model suggests beginning with courses that provide an overview of the technological systems. The narrow middle sequence is made up of courses dealing with specific information about each system as well as skill development. The broadening of this model from the specific narrow middle directs the curriculum toward courses that allow the future teacher to explore the interrelationship of the specifics. These courses reinforce adaptation of content to a variety of situations and require the utilization of problem-solving abilities.

TECHNOLOGY EDUCATION CURRICULUM STRUCTURE

Technology education curriculum content should have intrinsic merit that would stand up under the scrutiny of classical scholars (Friedman, 1980). Technology education, as a discipline, denotes a field of study in the same way that geology, biology, or anthropology are used (Dyrenfurth, 1984). If it is agreed that change is basic to technology, then it should also be accepted that technology education is a constantly changing curriculum with certain elements periodically being eliminated and others being added (Pullias, 1987).

Content

The identifiable domains and capabilities for a technologically competent individual may be stated as the possession of a broad technological knowledge together with the required attitudes and physical abilities to implement that knowledge in a safe, appropriate, effective, and efficient manner. Therefore, attaining technological competence involves each of the domains of human behavior. Prior to developing an instructional strategy, the cognitive, affective, and psychomotor skills that are to be taught must be defined and their interrelationships specified.

Cognitive development has been given the greatest attention throughout the history of formal education. Virtually all school progress is defined in terms of grades, subject areas, and clock hours, and is measured in terms of how much a student knows and is able to indicate through examination. For most educators it is relatively easy to define things to know and ideas to conceptualize. It is imperative that identifiable cognitive capabilities be included in a technology education program.

In addition to the cognitive domain, technologists also find themselves concerned with the affective domain. As technology forces new social, cultural, and economic relationships, technology educators must consider even more seriously the issues of values of technology on society. Affective development involves positive and/or negative feelings, attitudes, interests, appreciations, values, morals, character, and personal and social adjustment. Identifiable affective capabilities must be included in a technology education program.

Students learn technology by actually experiencing the activities and processes of a technological society. The psychomotor domain is concerned with movement behaviors: manipulative and motor skills, and arts requiring neuromuscular coordination. Therefore, when one performs purposeful psychomotor activities, they should involve the coordination of the cognitive, affective, and psychomotor domains. It is imperative that key psychomotor capabilities be included in a technology education program.

The Jackson's Mill Curriculum Project (Snyder & Hales, 1981) provided the profession with a sound theoretical basis for curriculum content. Scope and sequencing models have provided ways in which courses within that content might be organized. It therefore becomes necessary to provide organizational strategies for the content within individual courses.

The Systems Approach

The systems approach to organizing content is based on the model of input \Rightarrow process \Rightarrow output \Rightarrow feedback (see Figure 2-7). When the systems model is used to develop content for courses within a technological sequence, the replacement of terms within the model results in a technological systems model (Jones, 1983). Input is replaced with

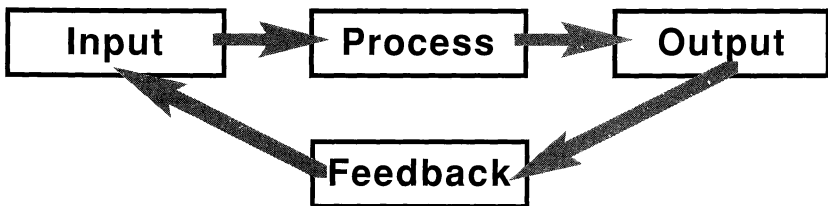


Figure 2-7. A systems model.

resources, process with technical process, output with applications, and feedback with technological impacts (see Figure 2-8).

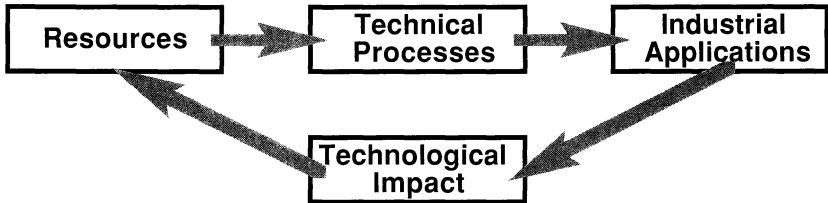


Figure 2-8. Technological systems model. (Jones, 1983)

Within the context of this model, resources refer to the **inputs** to the system such as tools, materials, people, and money. Processes are the ways in which the resources are used. Application is how and where the processes are used, and the impacts are the effects of the system on the environment and/or society.

Utilizing the technological systems model to derive content requires adding specifics to each of the model components. It is these specifics that make up course content. An example of content as it fits into this model is shown in Figure 2-9. It is important to keep in mind that Figure 2-9 is merely a sampling of the content for a given course. It is, however, indicative of how the model is used to organize that content.

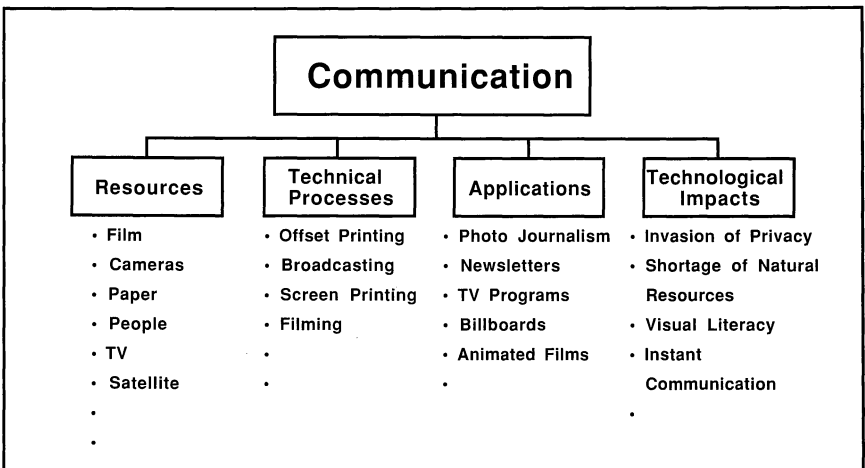


Figure 2-9. Course content for communication, derived using the technological systems model.

Integrating the Systems

As Jones (1988) points out, a **complete** job of teaching the technological systems cannot be accomplished without teaching each system in relation to every other. For example, production systems do not exist in total isolation from communication, construction, and transportation systems. While selected portions could be taught in isolation, to teach one of the systems as a total concept, the other three systems must be included.

Jones (1988) goes so far as to suggest that "Technology education teachers should not try to separate the systems" (p. 107). Integrating the systems is the natural process of teaching technology education. It does not require special preparation or inclusion on the part of the teacher; it is already there, neatly tucked into all technology-based curricula (Jones, 1988).

What appears to be one of the easiest places to assure integration of the systems is within the application component of the technological systems model. For example, when studying communication with respect to the technological systems model, integration of the systems can be accomplished by studying the way in which various communication processes are applied within transportation, production, and construction systems.

Methodology

Concepts develop as a result of perceptible instances (experiences). Words give these concepts a name. Without experiences, it is extremely difficult to learn any type of information. Whereas direct experience is the most concrete level of presenting information, language or verbal symbols are the most abstract level (Scarborough & Blankenbaker, 1983). If students are taught to-learn-how-to-learn-to-use, rather than how to use technological innovations, then not only will they have the direct experience but, in addition, they will be more able to transfer the learning process to technological innovations of the future (Kozak, 1982).

The technology education laboratory dedicated to the transfer of learning should truly be a laboratory. The equipment should be easily mobile since the entire laboratory needs to be designed for flexibility. Tabletop technology and many computers are integral components. The mobility of the equipment permits the laboratory to be constantly configured to facilitate the students' pursuit of learning objectives (Pullias, 1987).

SUMMARY

The exponential growth of technology is affecting every aspect of life, not only the industrial component of society. To use the example previously cited in this chapter, today's students need to know not only how composite structures are produced and how to make projects from them, they also need to know how to live with composites, how composites have become an integral part of their everyday life, and the effects composites will have on their future. However, understanding technology does not imply only a global understanding of the technological world, but also includes a knowledge of, and capability with, technology in the individual's environment—coping with an evolving society.

Technology education must be the preparation of people to exist in, and to relate to, a rapidly changing world. Technology educators must include all levels within the domains of learning in their teaching. Technology educators must also develop in students a cohesive philosophy of technology, and an appreciation of the interrelatedness of all technological systems.

SECTION II

KEY PERSPECTIVES ON TECHNOLOGICAL LITERACY

This section's primary intent is to bring **outside** perspectives to the field. The purpose is to enrich the scope of the perspectives from which we view the key outcome of our profession's practice—namely technological literacy.

Cultures throughout the world are experiencing technologically-induced change. Much, if not all, of the world is concerned with the impact of technology—on their individual societies and the related development, productivity, education, and quality of life. Given this, does the concept of technological literacy exist elsewhere in the world? If so, what does it mean to others? How should international perspectives be included in the development of a model for technological literacy? Should the United States and/or our profession continue to focus primarily inwardly?

This section is dedicated to gainsaying the self-centricism of much of our profession. It begins with Jule Scarborough's key insights and observations from overseas. She reviewed previous studies as well as conducted her own ambitious international research in the quest for perspectives directly useful to this yearbook's purpose.

Subsequently, Stevens blends creative expression and thoughtful insight to demystify what economists think about technological literacy. He considers this characteristic as one source of fuel to power the engine of economic growth. Technological sophistication promotes economic growth and economic growth demands technical understanding. Then he shares the economic perspective by assessing the merit of investing in technological literacy; by analyzing technological literacy as an object of choice; and by exploring the rules that determine whether, when, and how much technological literacy is sought. He concludes by outlining how economists think about who does, and who should, pay for improvements in technological literacy.

Because so much of life, including technology, is impacted by government, labor, and the private sector, these arenas served as the focus for the next chapter in this outside perspectives section. Governments establish laws that govern the monetary and economic systems of nations. Cooperation between the government and the private sector

can provide the policies and capital to reindustrialize economically- and technologically-stressed industries. All sectors are increasingly faced with political and public policy questions that have a strong technological base. With over half of the American labor force being white collar workers, people who work primarily with information outnumber those who work with their hands. Global market positions of advantage will go to the nations with the most technologically literate workforce.

The workplace of the future will be built around concepts such as entrepreneurship, intrapreneurship, teamwork, quality circles, and matrix organization. Governments are social institutions that are established to serve and protect their citizens. Since governments regulate technology to protect the public interest, governmental leaders must have a high level of technological literacy. However, it appears that relatively few elected officials have technological backgrounds, and so it is not surprising that their policies and operations are undermined by this weakness. Society must become genuinely concerned when people who are not technologically literate establish policies and develop regulations that impact technology.

Organized labor too is keenly aware of the effects of technology and it is working hard to empower its members to cope with technology. The influence of labor, the private sector, and government on technological literacy is explored by James L. Barnes, Dennis Chamot, and Thomas L. Erikson.

The view of what education encompasses is as diverse as the number of people who are asked. Significant among the more global indicators of overall progress in education are the positions adopted by its key associations. Author M. James Bensen examines the positions of leading educational associations and purposefully emphasizes those outside the technology education profession's core. Technologically literate people are able to handle their daily lives with confidence and purpose as a result of their ability to deal effectively with their surroundings. Educational experiences must provide people with the opportunity and means to gain a measure of technological literacy.

Michael Dyrenfurth ends Section II of this yearbook by undertaking to synthesize a new model for technological literacy. The contributions of this section's authors served as primary inputs for this chapter's two main subsections: Implications for technological literacy and definitions of technological literacy. After an initial exploration of the meanings of literacy and technology, several definitions of technological literacy are presented. These are followed by selected models of tech-

nological literacy as found in the literature. Given the review of the literature, in addition to the yearbook chapter authors' input, a new model of technological literacy was deduced. This model, obviously only one of the many possible, highlights the key characteristics of technological literacy that surfaced and that represent essential elements in achieving efficiency in today's technological world.

CHAPTER THREE

INTERNATIONAL PERSPECTIVES ON TECHNOLOGICAL LITERACY

by

Jule D. Scarborough¹

Globalization is taken for granted in today's business and technological arenas. Education, however, seems to be much more inwardly-focused than the commercial worlds. The technological pressures experienced by all peoples of the world is clearly enormous. All are facing rampant change, workforce adjustments, and competitive pressures engendered by the creation and use of new technologies. Undoubtedly their cultures are also experiencing technologically-induced change. Stemming from the belief that Americans can learn much from practices in other countries, this chapter sought to bring to our profession key insights and observations from overseas. It sought to answer how the education systems of other countries are meeting the challenges of technology.

The problem of making comparisons internationally is one of really understanding the context characterizing the efforts of technological advancement in each country as well as the educational context within which the concept of technological literacy has to be addressed.

Does the concept **technological literacy** really exist elsewhere in the world and, if so, what does it mean? What kind of programs are used to address its development? What issues are associated with the concept and these programs?

During the late 1970s, the concept began to receive serious attention in the United States and Europe. In the 1980s, professionals in the field of technology education, vocational education, and science education began to evolve various definitions of technological literacy. Some were even striving to develop a **test** or **measure** of technological literacy.

Recent efforts are developing conceptual frameworks that place the development of a technologically literate person comprehensively

¹Jule D. Scarborough is Professor in the Department of Technology, at Northern Illinois University, DeKalb, Illinois.

across all levels of education and integral to general education. Many disciplines are working at this challenge. Clearly, though, much of the movement towards technological literacy has been initiated by the technology and vocational education sectors. Science education did identify the importance of addressing related issues among man, science, and technology; however, this thrust aims closely at traditional science goals rather than to the broad understanding of technology and praxiological capability demanded by our culture.

RATIONALE

Why should we look at the international scene? After all, the U.S. has been, and continues to be, the leader in development and technology. Yes, other countries are now making significant technological strides as well (e.g., Japan and Germany), but the U.S. is still the major leader in developing new technology.

Educationally, though, it seems clear that the U.S. educational reform is floundering. Comparative assessments acknowledge that our system is not delivering either the level or nature of education required for success in today's competitive society. Despite the rhetoric, we have not really changed the system so that our quality has improved—except for isolated sites. Nevertheless, a good part of the world still looks to the U.S. for determining what they should be doing educationally, industrially, and developmentally.

The drive to improve their quality of life spurs other countries to invest greater proportions of talent and support in addressing educational goals. Much good work is done and much can be learned. Also, it is important to remember that a country as rich as ours bears a social responsibility to help struggling societies advance their quality of life. Our world is one of contradiction. There are dual social systems within single countries. Wealth, education, and quality life coexist with desperate poverty, illiteracy, and lack of access to life's basics (i.e., food, shelter, water, and disease immunization) in first, second, and third world nations. Not one country is exempt from such a dichotomy.

Given the preceding, this chapter strives to bring about a dual awareness: first, that no longer is it appropriate to focus inwardly on our country alone; and second, technology, in all its application arenas, plays a most significant role worldwide.

WHAT DOES THE INTERNATIONAL LITERATURE REVEAL?

As might be expected, most of the available American literature focuses on technology education (not technological literacy) and, currently at least, very little international literature is targeted directly on technological literacy. Gradually, however, there seems to be increased international consciousness of the concept although much must still be inferred from discussions about technology education programs.

Altogether, the author's literature search revealed documentation about Europe, Scandinavia, the U.S., Canada, Australia, the U.S.S.R., Asia, and Africa. However, no information about South or Central America was found. Interestingly, an examination of a cross-section of countries revealed a consistency among their objectives for technology education.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) (1983) conducted a study of 37 countries concerning technology as part of general education. More recently, Dyrenfurth (1988) reported the results of an international interview series and, specifically for purposes of this chapter, Scarborough also conducted a systematic mail survey.

The UNESCO (1983) study included developing countries as well as those that were highly industrialized. The programs varied widely and many included a slant toward vocational education. However, it was evident that the need for a level of technological literacy in these countries was recognized. In the conclusions it was stated²:

The findings of this survey clearly show that the education systems examined have introduced, or are on the point of introducing or developing, technological components into general education curricula. This trend implies more than a mere revision of curricula. It aims at a change in behavior, the gradual integration of general and technical education and the adaptation of education to working life. Some countries claim that technology taught permeates all the courses in general education schools. In other countries, technology education is in fact an introduction to manual activity whose goal is not preparation for employment but rather the development of the child's liking for handicrafts. In a third group of countries, the technological slant is taken up for

²Eds. Note. M. J. Bensen authored these paragraphs for chapter 6 of this yearbook. For purposes of cohesiveness they were moved to this (Scarborough's) chapter.

reasons of general education objectives, and is an attempt to understand often in a theoretical way, the modern technological universe. In the last two cases, technology education carries with it an intrinsic **general** functional education that enables those receiving it to integrate usefully into society, even if they do not continue their education. Nevertheless, the best of these pupils will be capable of exercising on society—or at least on their environment, taken in the broadest sense of the term—a living influence leading to the improvement of that society (UNESCO, 1983, p. 23).

UNESCO's (November 1984, pp. 3-4 and 1985, pp. 9-15) rationales describing technology education as a part of general education contain the following implications for technological literacy, i.e., that technology education develops in students a/an:

- mastery of a basic knowledge, and understanding, of technology and its links with science
- awareness of technology and impact on environment & life
- knowledge of the "need-to-product" process
- ability to design & construct products
- understanding of the use of materials and energy
- reasoning skills
- critical thinking skills
- set of technical & cognitive skills (with respect to technology and science)
- understanding of social & other impacts & implications of technology
- set of positive attitudes & values, e.g., to work
- ability to chart likely future directions of technology
- ability to work in teams
- propensity for safe work habits
- sense of the evolution of technology
- understanding of the use of materials, processes and techniques of technology and the ability to apply this
- ability to engage in systematic decision-making
- capability for careful observation
- ability to collect data
- set of analysis, interpretation, & research skills
- capability for problem-solving & planning
- enhancement of career maturity
- set of tool & equipment use, making skills, & manipulative skills
- capability for design, fabrication, evaluation & realization
- sense of the historical evolution of science & technology
- valuing of the development, conservation and appropriate use of resources

- appreciation of agriculture and industry
- fostering of creativity & innovation
- understanding and ability to use communication skills, including graphic communication

Table 3-1 (page 59) compares the results of the UNESCO study, Dyrenfurth's (1988) study, and the present study (which will be discussed later in this chapter). However, as the table reveals, one can see that "contemporary" technology education appears in the responses from some countries even though the programs are predominantly vocational. It is clear from the UNESCO-sponsored studies and Dyrenfurth's studies that vocational education, as we traditionally understand it, is offered throughout most of the countries examined. Also, at the risk of oversimplifying the report, it seems that at least the name **Technology Education** was usually incorporated within, or associated with, vocational and technical education. What is unclear in these studies is the exact definition, role, and nature of technological literacy. Although these studies reveal a growing international awareness of the concept of technological literacy, they also indicate that implementation of the concept is still in the infancy stage.

Canada was among the more developed in this vein. Fleming (1987) published a review of Canada's educational goals and the findings. He noted that technological literacy carefully combines literacy and technology thrusts. From the Canadian perspective, literacy empowers one to create new, more powerful cultural forms by sponsoring thought and imagination about possible alternatives.

The Canadian definition of literacy is "the ability to comprehend, through reading the texts of others, what is new information" (p. 7). Their definition of technology, adapted from Pacey (1983), is: "the application of scientific and other knowledge to practical tasks by ordered systems that involve people and organizations, living things, and machines" (p. 9). Thus, when combining these two concepts and definitions, Fleming reasoned that knowledge of technological practice, with the empowerment assuring because one is literate, enables one to examine and question the:

ideas of progress through technology, appropriate technologies, benefits and costs of technological development, economic models involving technology, the personal decisions involving the consumption of the products of technology, and the decisions made by the managers of technology as they shape the application of technology. (p. 11)

Table 3-1. International perspectives on technology, technological literacy and related coursework³

Country	1988 Scarborough Definition of Technology	1988 Scarborough Definition of Technological Literacy	1988 Dyrenfurth Concepts Surrounding Technology	1983 UNESCO Technology as Part of General Education
Argentina				"Technology education in all courses 1-6."
Austria				Seemed to be vocationally oriented.
Belgium	"Component of present-day culture which originates in relations focused on humanization between people and nature."	Indicated problem of translating technological literacy into Flemish or Dutch.	Technological literacy: "To be capable of facing a problem, to see a problem, to think about a solution, to have it done or to do it yourself."	"4-8 hrs./wk. technological education."
Brazil				Seemed to be vocationally oriented.
Canada	"The exploitation of science for the achievement of practical purposes."	No definition—indicated that there are no future plans regarding definition presently but the Science Council of Canada has dealt with this in the past—did not provide that information.	"Something that is applied, practical, not too theoretical." Technological literacy: "Vocabulary pertaining to technology and computers, management systems and terms, hardware and software."	
China	Author's observation in country: 1981 & 1987. Traditional manual skills/training very basic—usually nonexistent. Mostly agricultural in training. "Futures" reform began 1987 for training program for industrialization.			Seemed to be vocationally oriented.
Cuba				"Special Basics of Technology course." Seemed to be vocationally oriented.

³Eds Note: This table presents a set of insights and perspectives to provide a sense of world-wide progress in addressing the challenges of technology. It does not purport to represent official position of ministries/departments of education. Also, the reader is specifically cautioned to avoid over-generalizing. The entries represent individual, albeit well-positioned, observations (by inhabitants, never outside observers) of a country's status with respect to technology, technological literacy, and technology education. As such, the intent is to contribute to the documentation of international approaches to technology and technological literacy. Readers are encouraged to continue the process by filling the gaps and improving the entries.

(continued)

Table 3-1 (continued).

Country	1988 Scarborough Definition of Technology	1988 Scarborough Definition of Technological Literacy	1988 Dyrenfurth Concepts Surrounding Technology	1983 UNESCO Technology as Part of General Education
Denmark	Denmark described—did not define—concepts separately; "Change is key word in connection with concept 'new technology.' The interaction between technological change, organizational change, and changes necessary in personal qualification are the focus of education . . . upper secondary requires computer lessons integrated into curriculum . . . aim of computer instruction is insight into electronic data processing, its areas of application, and for students to gain experience in solving problems using computers." They teach the use of computers in vocational education for process control, machine control, calculation, design, construction, and planning applications. Use computers broadly as tool—moved away from computer science as source.			Seemed to be vocationally oriented.
Egypt				"4 hrs./wk. technology 4-8, 5 hrs./wk. technology 9, 5 hrs./wk. applied science 5-9."
England (U.K.)	"The application of scientific knowledge in the design, making, and evaluation of a product, that product being the solution to a need identified by the student." "The deliberate application of human creativity, endeavor, and knowledge to the solution of problems linked to the physical needs of individuals of social groups."	No definition; however, indicated that there is "the capability to apply a range of technologies—often taken from the following list: the knowledge of scientific components most frequently used as sources in designing and making are: materials, electronics, digital microelectronics and computer control, structures, pneumatics, mechanisms, instrumentation."	"The identification of the needs of man and the endeavor to satisfy these needs by the application of knowledge and the use of materials, and energy." Technological literacy: "Never heard it used; strong connotation of being able to do! Problem solving in any setting."	"Technology education 3-6, and basic technology projects 7-12."
Finland	"To work on materials, to change form and size of materials; as well, special technologies, e.g., welding technology." The major units/components are: "materials are the basis but it is more and more replaced by the importance of information technology."	At present, Finland has no definition or conceptual description of technological literacy. Future plans are "to introduce it in 1989 as part of technology education as one of its aims as a part of general literacy and literacy programs in the world."		"Handicrafts."
France				"Handicrafts 1-5, technical and craft education 6-7, and craft education technological options 8-9."

(continued)

Table 3-1 (continued).

Country	1988 Scarborough Definition of Technology	1988 Scarborough Definition of Technological Literacy	1988 Dyrenfurth Concepts Surrounding Technology	1983 UNESCO Technology as Part of General Education
German Democratic Republic (then)	"Technology is the know-how and creative process that may utilize tools, resources, and systems to solve problems and to enhance control over the natural and man-made environment in an endeavor to improve the human condition." "Technology combines sciences in a complex manner; technology comprehends the relations between the different sciences; technology opens the content of productive work; therefore, technology is one of the best pedagogical means."	"Refers to Polytechnical Education as kind of general education which pursues in our sense the principle of connecting 'learning, working and sports.' The 'Polytechnical Principle' of our school is realized by the interrelation of all subjects. Each single subject provides practical aspects, opportunities of our application to many spheres of social life, in which technology plays an essential role. Particular potentials to realize the life-oriented principle of education have been opened up by introducing the special subject of 'Polytechnical Instruction' . . . the subjects of polytechnical instruction . . . have developed to be a pillar of the educational system . . . brings technology and real life into the classroom . . . also introduces the students to the field of production." "Grades 1-6 handicrafts, 7-10 introduction to socialist production, technical drawing and productive work."		
Federal Republic of Germany (then)	"Using the possibility of nature (science laws), doing what is economically reasonable and desirable for man and environment." (Survey 1)	"We are looking for these qualifications: ability of knowing (cognitive), ability of doing (practical doing), ability of judgment (desirability of technology)."	"There are many varied perspectives. <u>Technic</u> is used; typically it refers to industrial products, computers, all 'new stuff,' e.g., lasers, not telephones."	"Education for work 6-10."

(continued)

Table 3-1 (continued).

Country	1988 Scarborough Definition of Technology	1988 Scarborough Definition of Technological Literacy	1988 Dyrenfurth Concepts Surrounding Technology	1983 UNESCO Technology as Part of General Education
Federal Republic of Germany (then) (continued)	<p>"Handling materials, energy, and information in the following areas: work and production; tools and engines; civil engineering; building an dwelling; energy supply; communication and information; automatization—all by using specific technical methods, e.g., planning drawing, producing, controlling, optimizing, maintaining, repairing, etc." (Survey 1)</p> <p>"'Technology,' as it is addressed in educational programs, means mainly what we call the new technologies in the area of technology of information and communication processing." The major units/components are: "computer science, electronical data processing (... used in constructing, manufacturing, administration, and organization), and the new media' of mass communication." (Survey 2)</p>	<p>"There is a conceptual description of 'basic technology education' as part of 'technology education.'" This concept was developed by [German name]—KMK—in 1987. The KMK is an institution in which representatives of the states and the federal government are coordinating their educational policies." (Survey 2)</p>	<p>Technological literacy: "Typically the term is not used but Kultur Technic is used to refer to reading, writing, calculating." In response to what a term means to this individual, "Technic, the use of technology, as we do numbers and letters. It is difficult to even translate into German . . ."</p>	
Ghana				"Elementary technology and study of crafts 1-9, and craft training 9-10."
Guinea				Seems to be vocationally oriented.

(continued)

Table 3-1 (continued).

Country	1988 Scarborough Definition of Technology	1988 Scarborough Definition of Technological Literacy	1988 Dyrenfurth Concepts Surrounding Technology	1983 UNESCO Technology as Part of General Education
Hungary				Seems to be vocationally oriented.
India	<p>"Technology is conceived as the total knowledge and skills available to the society for industry, arts, science, communications, etc. It is that branch of knowledge which basically deals with the industrial arts. It is applied science which has commercial utility."</p> <p>Author's observation: 1989. Educational reform underway to deal with literacy—introducing reading, writing, arithmetic, entrepreneurship and low-level technologies to rural areas. Very basic, but making progress.</p>	<p>No definition given but explanation was that India is developing—priority is adult, especially female, for 70% of the population. Scarborough (1989) documents a focus in India on fundamental technology implementation and literacy, i.e., water pumps, coal stoves, etc. General awareness is being attempted through institutions such as Council of Science and Technology.</p>	<p>"It is a balance of knowledge and invention. It takes us forward like a scientist as contrasted to a technical."</p>	Seems to be vocationally oriented.
Italy	<p>"The subject Technology is referred to as 'Educazione Technica' which is broader than just the technical aspect, but rather it also includes the reasoning and logic behind such ingenious work."</p>	<p>"The base cultural element which is applied to the physical aspect."</p>		
Japan	<p>Author's observation in country: 1985 & 1987. Traditional Industrial Arts/Vocational Education, grades 7-14, as well as Computer Education.</p>			Seems to be vocationally oriented.
Kenya	<p>Author's observation in country: 1989. Educational systems/programs lack laboratories of any kind. Some manual skills—very basic.</p>			
Kuwait				Difficult to interpret.

(continued)

64 **Table 3-1 (continued).**

Country	1988 Scarborough Definition of Technology	1988 Scarborough Definition of Technological Literacy	1988 Dyrenfurth Concepts Surrounding Technology	1983 UNESCO Technology as Part of General Education
Mauritius				"Creative design and technology."
Mexico	Author's observation in country: 1989. Educational programs very basic; very little in laboratory; minor basic skills.			
Morocco				"Handicrafts 1-5, technology education 8-9."
The Netherlands	"Three levels can be distinguished: (1) physical objects and artifacts; (2) refers to activities and processes, e.g., welding; and (3) knowledge and abilities to design and produce."	"To introduce pupils in our common technological knowledge which is an essential part of our culture, through working with materials, using tools and machines, investigating situations, designing solutions to solve technical problems."		
Nigeria	"The use of knowledge primarily derived from the systematic investigation of the forces of nature to satisfy man's needs, is the cornerstone of progress upon which Nigeria can depend to attain self-reliance and self-sustaining development.			
Pakistan				Seems to be vocationally oriented.
Sierra Leone				Seems to be vocationally oriented.
Spain	"An activity that involves theory and seems to be vocationally oriented practice; coordinating diverse knowledge to solve problems, needs or man's desires."	"The objective is to have pupils of 12 and 16 years of age to be capable of recognizing, comprehending, and interpreting their technological knowledge so that they can orient themselves and make rational decisions relative to the three great nuclei of technology: matter, energy, and communication, and, at the same time, help the development of their intellectual and manual capabilities."		
Sri Lanka				Seems to be vocationally oriented.

(continued)

Table 3-1 (continued).

Country	1988 Scarborough Definition of Technology	1988 Scarborough Definition of Technological Literacy	1988 Dyrenfurth Concepts Surrounding Technology	1983 UNESCO Technology as Part of General Education
Sudan				Seems to be vocationally oriented.
Syria				Seems to be vocationally oriented.
Tanzania				"Technology education, including science, geography, agriculture, history, and home economics 1-7" and seems to be vocationally oriented for upper levels.
Tunisia				"Introduction to handicrafts 5-6; preliminary course 7; technology, including technical drawing 9." "Mathematics and technology section 10-13, and technical drawing 13."
United States	Varied perspectives from state to state. Many focus on industrial technology whereas others address the larger focus of technology. Many different arrangements of components are used but the Jackson's Mill derived manufacturing, construction, communication and transportation systems are most prevalent.	The understanding of, and capability with, technology. Typically technological literacy is considered to be a characteristic that exists at various levels, i.e., that one could be highly or moderately technologically literate or anything in between. Technology literacy means <u>understanding</u> the technological and scientific forces shaping our lives, and in being able to <u>act</u> on this understanding for our <u>personal welfare</u> and <u>common good</u> (STS, 1986).		"Technology education 1-8, vocationally oriented upper levels."
Uruguay				"Technology 7-9," vocationally oriented above.

(continued)

Table 3-1 (continued).

Country	1988 Scarborough Definition of Technology	1988 Scarborough Definition of Technological Literacy	1988 Dyrenfurth Concepts Surrounding Technology	1983 UNESCO Technology as Part of General Education
Venezuela	Author's observation in country: 1989. Strong oil industry, but educational programs lack development. Have basic traditional materials processing all levels—engineering laboratories similar to traditional junior high school industrial arts laboratories. Just began "Experimental Universities" which are focusing on needs of communities and industries, but very few programs and no laboratories are developed.			
Zaire	Author's observation in country: 1989. Industrial programs or technology-related program are almost nonexistent.			"Handicrafts 3-5, technology education 7-8."
U.S.S.R.	<p>"A specific form of the process of development of the productive forces in contemporary conditions directed toward the creation of the sum total of conditions for the realization of the needs of society in perspective."</p> <p>"The major units/components are: the characteristic traits of the process of the development of technologies include the fact that they occur in stages, the presence of sources and factors which determine the transition from one phase to another, the mechanism of progressive accumulation of knowledge which creates the possibility of obtaining new data in a prioritized field of knowledge which brings about the discovery of a new technological direction. For the development of technologies is characterized by the conception of a forward-looking technology within the framework of what exists and has come before, the expansion of possibilities and the subsequent 'absorption' of old technologies by a new one while preserving 'key ideas.'"</p>	"There exists the concept 'technological literacy' which is the quality of acquiring the building principles and the rules of the development and exploitation of technology."		Seems to be vocationally oriented.

Fleming also negates the belief that technology is applied science. His position is that each, science and technology, are identifiable disciplines, each with its own body of knowledge. Consistent with the traditionalists' view of science, Fleming views science as the "producer of knowledge" and technology as the "consumer of that knowledge" (p. 11).

Across the Atlantic, in the United Kingdom, much of significance had been evolved. Todd⁴ writes that:

the U.K. Craft Design and Technology movement was deeply rooted in the traditional practice of handicraft that stretches back to the late 1800's as was the U.S. Industrial Arts movement. Interestingly, it was in 1904, the same year that the name **industrial arts** was proposed in the U.S. that building regulations in the U.K. required that every secondary and board school have a workshop (Todd, 1985). The curricular area of handicrafts in both countries, by whatever title was applied, saw periods of significant growth throughout the next fifty years.

By mid-century a new effort for change was evolving in the U.K., almost simultaneously with the emerging effort in the U.S. Professional discussion about technology as a part of schooling started in the 1950's and resulted in a change of thought regarding the study of technology. It was during the 1960's that an important impetus for change came from Her Majesty's Inspectorate (Department of Education and Sciences, 1967). The concern of HMI was represented in its identification of the need to broaden the experiences for students beyond the standard craft skills to involvement in design and technology activities. In fairly short order, discussion resulted in action and several efforts were initiated. Through the work that followed, the movement in the United Kingdom to include technology, and indirectly technological literacy, within the school curriculum was on its way. The long-term result of that effort is now evidenced in a comprehensive curricular organization that includes **design and technology** as an essential part of schooling for all students (Department of Education and Sciences, 1985 and Department of Education and Sciences, 1989).

⁴Eds. Note: Todd authored these paragraphs for use in chapter 1 of this yearbook. For purposes of cohesiveness, they were included in this (Scarborough's) chapter.

The emergence of technology within the school curriculum has not been limited to the U.S. and the U.K. Although it is difficult to understand the exact meaning ascribed to the word **technology**, several countries included the study of technology as a part of their experience for students. For example, such new content was included as part of the curriculum in France nearly thirty years ago. Since then many of the western European countries have introduced their own version of technology education into the curricula of their schools and during the last ten years literally dozens of countries have adopted the terms technology and technological literacy.

Elsewhere, the Council of Europe's 1980 conference (Maley, 1981) reached some consensus that there are two trends in curriculum for technology. The first trend involves the transfer of knowledge and manipulative skills to students studying in various technological areas. The second trend addresses and acknowledges: (a) technology as the creation of an artificial world based upon society's needs and interests, (b) technology as being subject to societal change, and (c) the obvious difficulty in predicting what technological knowledge would benefit students (p. 15).

Across the channel, Streumer and Doornekamp (1988) conducted a study which indirectly addresses technological literacy. They developed a Technology Achievement Test which aimed at measuring:

- thinking and acting in a technical way, in the sense of working on and processing materials;
- thinking and acting in a technical way, in the sense of dealing with products of technology such as: using energy-consuming devices; designing action, projects, prototypes or products; and
- introductions to technical phenomena.

Most of the relevant documentation presented a humanistic rationale to the need for technology education—an education that acknowledges the importance of providing educational experiences for students that would increase their ability to live, individually and collectively, as productively as possible in a highly technological environment. The rationale includes arguments pointing out the importance of students increasing their capabilities to become part of the movement to make their society's **quality** of life better through critical thinking, problem solving, and astute analysis.

Van Poucke and Wansteenkiste (1985) presented a report on society and the study of science, mathematics, and technology. While they do

not use the term **technological literacy** directly, they did address most of the important issues evolving from technological literacy. They group the three content fields in such a way that there seems to be strong interdependency. From their perspective, there seems to be a more constructive attitude today toward technology. Perhaps this is because humankind is now facing a dilemma in that society cannot survive without further scientific and technological development. However, it seems ironic that this very development is itself a threat to man and nature.

Van Poucke and Wansteenkiste (1985) also lamented the lack of understanding of the analytical approach to explaining phenomena. For example, they observed that the concept of the whole being more than the sum of its parts has been forgotten. They state that science has long been empirically-based, but in a manner which tends to leave out practicalities. Instead, they call for a coordination of science, mathematics, and technology in education. They strongly press the point that these content areas can no longer operate in isolation from each other or from other fields of knowledge.

Internationally, the issues of **Technology in General Education** and **technological literacy** have been addressed by UNESCO (1985), de Vries (1987), Dyrenfurth (1987), Todd (1987), Dyrenfurth (1988), Vohra (1988), and many others. Key points of these authors include addressing technology education: (a) through the teaching of science (nontraditionally through technology); (b) through the complexity of the technological environment; (c) through the person as the center of technology, integrating all dimensions of technology through all disciplines; (d) through the ability to do, recognize, and use technology, as well as understand its impact on one's life; and (e) through studying industrial systems.

Vohra (1988) promotes a general education perspective that meets the needs of the majority of individuals who are going to live in an increasingly technological society. He addresses the needs of the average person rather than the technologist or technician. He supports an educational approach that develops a technological literacy that "allows people to function intelligently within the complexity of their technological environment" (p. 28). In rationalizing this, he acknowledges definitions from various sources across the world and concludes that, in defining technology, one must accept that:

technology is the know-how and creative process that may utilize tools, resources and systems to solve problems to enhance control over the natural and man-made environ-

ment in an endeavor to improve the human condition... reflects creativity, design and skills for the utilization of tools, materials, resources and systems for decision-making, problem-solving and environmental control as essential elements of technology (p. 14).

In a special topic-focused *School Shop* (1988, April), over a dozen authors described industrial education in the world-wide perspective. Each of these articles discusses the status of industrial/vocational education and various movements toward reforming national programs. It seems clear that inherent within the reforms in industrial/vocational education in some of these countries are obvious efforts to address technological literacy. In many cases, the industrial/vocational programs are very technical and the reforms do not change that focus; however, math and science, as well as the technology component of these programs, are being strengthened in an attempt to address technological advancement.

The U.S., Europe, and Canada appear to be the leaders in **documenting** what might be conceived of as the contemporary concept of technological literacy. Fleming (1987) incorporates the addition of empowerment more articulately than Americans do, but empowerment is certainly inherent in the evolving U.S. definition.

Currently, among the key characteristics of technological literacy generally accepted throughout the international community of technology education are the scientific base of technology, the importance and impact of technology in the lives of people; and their ability to select, use, and apply appropriate technology to solve problems. It also seems that this definition falls directly in line with the rest of the developing world's approach to addressing technological literacy. It's just that the developing nations are not focusing on written or published definitions. Rather, they are striving for program implementation and/or reform. Inherent in their actions, however, is a focus on technological literacy from which can be deduced a direction for those of us seeking a definition.

INTERNATIONAL SURVEY INPUTS

Even though several studies have been conducted to ascertain what is happening internationally with technology education and the concept of technological literacy, they did not surface the information being sought for this yearbook chapter. Consequently, it seemed

appropriate to survey key countries in an effort to establish whether the concept of **technology** and/or **technological literacy** were evident in current educational objectives and if these concepts were defined. A questionnaire was sent to individuals in 32 countries. These individuals represented organized labor, economic, government, private, and education sectors. Twelve countries responded (see Table 3-1) but only from the education sector. These inputs were melded with those of UNESCO's (1983) and Dyrenfurth's (1988) studies.

Status of Responses to Technology's Pressures

Generally, the findings of the author's own study paralleled the UNESCO (1983) report and Dyrenfurth's (1988) interviews. Of course, when interpreting the results, it must be remembered that definitions vary according to the individual giving the information and, even with conscientious respondents, generalizing to whole countries (from individual responses) is fraught with danger. Fortunately, some respondents included national documentation with their completed surveys. In other responses, documentation was not available and individuals in national education agencies replied from their own agency's perspective. This gives a wide range of responses, but surprisingly there was consistency across the responses.

When comparing the definitions of technology, most respondents seemed to deal with scientific knowledge and the know-how of **doing**. They all seemed to address the value of skills in improving the physical realm of society. They also acknowledged human creativity and design and the application of knowledge to address the needs of humankind.

The responses differed more in regard to the definition of technological literacy. When asked to offer such a definition, only England (U.K.), the German Democratic Republic, the Federal Republic of Germany, India, Italy, the Netherlands, and Spain responded directly (see Table 3-1). Consistently, respondents supplied explanations instead of definitions. Often there were mentions of the concepts of: applying knowledge, doing, using technologies or scientific information, implementing technologies, working with materials and mechanical devices, and interpreting technological knowledge to improve the quality of life or social culture.

From the responses, it seemed that most approaches to education about technology occurred consistently through traditional industrial arts or vocational education types of courses and/or their current variants. Subjectively speaking, this seems true even in the U.S. It also

seems that the most common route to addressing technological literacy is through the same means. Yes, the U.S. and some European countries have begun to offer a broader range of technology education systems courses (e.g., transportation, communication, energy, and production), but the broad scale international implementation of curriculum about technology generally continues to occur in industrial/vocational education courses.

The Emerging Definition of Technological Literacy

If in fact a definition is emerging in the international scene, it takes the form of an awareness of the need to address the impact of technology in the daily lives of people. Currently, the majority of the world still addresses anything related to technology as conventional technical/vocational training although some countries are beginning to do so through enhanced science education as well.

One has to acknowledge the movement of the developed or western world to address technological literacy; however, the educational reality of the developing and underdeveloped nations is one of just beginning to address vocational training for employment, let alone the higher⁵ goal of technological literacy.

Todd⁶ observed:

over the past few years there has been an increase in international efforts that use technological literacy as a slogan and that consider the study of technology as part of the school curriculum. The number of countries and agencies has expanded significantly beyond what was reported a few short years ago (Todd 1985). Selected examples of those efforts, both old and new, follow. In England there is the work at the National Centre for School Technology at Trent Polytechnic in Nottingham, the National Network of Science and Technology Resource Centres, the Science Policy Research Unit at the University of Suffolk, the British School Technology Project at Nottingham and Bedford, the Technical Change Centre in London as well as the many universities and colleges involved in preparing technology teachers.

⁵with respect to Maslow's order of needs

⁶Todd authored these paragraphs for use in chapter 1 of this yearbook. For purposes of cohesiveness, they were included in this (Scarborough's) chapter.

Is there really a difference, or are the objectives across the world the same and is it just the contexts and specific implementation details that are different? Even the technologically advanced Japanese society teaches manual training at the technical high school or post-high school levels while simultaneously integrating intense computer training. Essentially, the U.S., Canada, and some European countries seem to be the principal agents pondering over and developing the contemporary **concept of technological literacy**.

When considering the technological literacy movement in the international context, one must consider the development stage of the countries being studied. It could be hypothesized that the developing and underdeveloped nations are in reality considering technological literacy synchronously, and each, in their own way, is working towards a technologically literate society. The absolute level of technology or of technological literacy might differ from that of the western world; but in the local context, advancement, the type of technology available, and the impact of technology are similar concepts to our concerns. Therefore, one must be careful to take into account a country's level of development when determining whether or not technological literacy is an education objective.

Given this, it appears that technological literacy is indeed a major education focus worldwide if the countries responding in this study could be considered a sufficient sample for generalization.

Many of the respondents stressed the learning of science through practical **skills**, application, know-how, and creative and problem-solving processes that utilize tools, resources, and systems. This incorporates theory, know-how, application of performance, and practice. In this manner, other countries are certainly at least considering the concept of technological literacy and are developing it appropriately for their own societal needs.

Because technology is pervasive on a global scale, technology educators are examining the practices of other countries to see what might be learned. In addition, there exists a quest for consistency in definition. More subtle is a desire to develop a curriculum that could address technological literacy across cultures and societies that differ in technological advancement. To date, little overt evidence has been found to support this goal.

Although many countries, emerging and developed alike, are addressing the concept of technological literacy, only four country's respondents shared definitions of any kind for technological literacy (see Table 3-1). Additionally, it should be noted that none of the cited

studies actually identified course titles specifically speaking to technological literacy. However, in reviewing the course titles that were secured through this survey, it seems that most courses were quite similar to traditional industrial arts or vocational education course titles in the U.S. This similarity was also documented in Dyrenfurth's (1988) and UNESCO's (1983) studies.

From his analyses and experiences, Todd⁷ notes that:

on the European continent efforts are underway at the Study of Technology and Society programs at the University of Leiden and at the Technische Hogeschool in Delft, both in the Netherlands. In Germany there are the efforts of the Deutsches Museum in Munich as well as, the Wissenschaftszentrum and the Wissenschaftskollegium in Berlin (Riis, 1986). In France, the first steps of establishing technology as a basic school subject and integrating it with science were taken nearly thirty years ago (Dodd, 1978).

There is also a growing body of research on attitudes of students toward technology emerging from the work of Jan Raat, Marc DeVries, and their colleagues from the Netherlands. Starting at Eindhoven's Technological University this work involves colleagues from Australia, Belgium, Canada, France, Germany, Hungary, Kenya, The Netherlands, Nigeria, Poland, Sweden, The United Kingdom, and the United States (Raat, 1986). The major focus of this ongoing research is to determine what 12- to 15-year-old students think about technology in order to facilitate curriculum planning and technology course development (Raat & de Vries, 1986).

Overall, there seems to be a healthy awareness that there is a difference between the **new** technology education and the **old** or **traditional** industrial arts, vocational education, crafts, training, etc., even for the developing countries. However, it is not obvious in the majority of countries responding to any of the surveys that there is a definite difference between technology education and vocational or industrial education. It is equally obvious that, even though there may be contextual differences, many of the responding countries claim to be concerned with technology and technological literacy—even if their approaches are not compatible with what we deem technology education to be.

⁷Todd authored these paragraphs for use in chapter 1 of this yearbook. For purposes of cohesiveness, they were included in this (Scarborough's) chapter.

Some countries are developing formal frameworks and definitional academic parameters of technology education while other countries take a more vocational approach in addressing the concept. Still other countries are introducing and implementing appropriate technology with no concern for mass understanding of technology. Regardless of the formality or informality of approach, however, the issues are clearly obvious within the respective national consciousness.

These concerns are often manifested through the implementation of technology, especially in the developing nations. The differences lie in the technical level and status of technological implementation. However, regardless of the level of technological advancement of a country, some technological impact is obvious. For example, when visiting industries and villages in India, one can observe very high-level technology in their electronics factories; conversely, however, in the villages, the government is trying to train villagers in technical maintenance of pumps so that they have access to water, and they are trying to get the villagers to use a different coal stove so that, when cooking, they inhale less smoke hazardous to their health. Wouldn't one consider such village technology issues as **literacy** issues, and the application of higher technology in its major industries to be **literacy** issues as well?

CONCLUSIONS

Among educators, there does seem to be a healthy awareness that there is a difference between the contemporary or **new** technology education as defined by the technology education profession of the United States and the **old** or traditional industrial arts, vocational education, and crafts training. Even the developing countries (i.e., those not industrially advanced at this time) appear to be extremely aware of the difference. It is obvious that many use the U.S. as their model.

Technological literacy as a concept, in contrast, does not seem to have spread as quickly or as clearly. In fact, there seems to be very little conscious awareness of it as a concept separate from **technology** within industrial/vocational and/or technology education. However, it does seem to be an implicit focus of these programs.

One significant concern to this author is that there seems to be little or no understanding of **technology education** or **technological literacy** outside the educational institutions. This survey was sent to labor organizations, national offices, economic development agencies, and

private sector representatives. Little response emerged from all these sources to suggest any concern for, or interest in, these constructs.

Given this context, then, the following observations are offered. Overall, according to the individuals responding to the surveys, the nations they represent are indeed considering the impact of technology on their societies and the role of technology in their educational programs. Some are only just beginning to define technology while others are considerably advanced in this process. There seems to be evidence of parallel (to our) thought on the definition (e.g., societal need, problem solving, technology education tied to general education, and the like). Technological literacy does not seem to be highlighted by definition separate from vocational training in developing nations, but it is obviously inherent in their explanations of technology-related programs.

Most of the countries had viable definitions with some versatility. The definitions did not seem to be directly linked to vocational education or to traditional industrial arts or their equivalents. In comparing these definitions, they all seemed, as mentioned previously, to deal with scientific knowledge and the **know-how** of doing. They all seemed to address the value of skills in improving the physical realm of society. They acknowledged human creativity and design and the application of knowledge to address the needs of humankind.

Overall, there seems to be a slow, but deliberate, international movement to consider technological literacy whether it has a separate conceptual identity or not. In developed nations, it seems to be addressed in the more sophisticated arena of the affective domain, psychologically focusing on the human/technology interface in industrial systems. In developing nations, it seems to be addressed in assessing and meeting specific technological needs of society through vocational training or the introduction to, and implementation of, appropriate levels of technology throughout these societies. Notably, there seems to be a worldwide lack of teachers properly equipped to deliver technology education in any of its general education manifestations.

Technology-related content seems to be consistently taught through industrial arts/technology education and/or vocational types of education. However, there does seem to be an additional thrust to reduce the lines of demarcation between science and technological/vocational education in the U.S., Canada, and some European nations.

The contemporary concept of **technological literacy**, as promoted by the ITEA and the Technology Education Division of the American Vocational Association, seems only to be a cause célèbre in the U.S.

and selected parts of Europe and Canada. The rest of the world seems to be dealing with technological literacy as a direct consequence of having more people with advanced levels of technological training enter their society.

There appears to be a correlation, in direction and action, between those developed countries struggling with definitions of technology or technological literacy and those countries dealing more pragmatically with trying to implement the use of **new** technology within the everyday lives of people. Both are working toward incorporating the issue of technological literacy into general education. Whether that effort is structured as we do it in the west, or is approached differently, is somewhat irrelevant. The thrust is the same.

The U.S., Canada, and the Netherlands seem to have the most public documentation dealing with technological literacy. Despite the mass of this documentation, a caution must be voiced. Given the well-deserved criticism directed at educators for a lack of a precise vocabulary, and for our unreliability in using it, popular and subtle concepts are often used interchangeably even if they are not meant to be interchanged. Since perspectives and implied meanings may differ from context to context, the sheer volume of discussion does not in itself demonstrate unanimous agreement on the thrust.

DISCUSSION — A PERSONAL PERSPECTIVE

Based upon the cross-section of documentation—UNESCO (1983), Dyrenfurth (1988), the present study, and this author's own international visits and observations—it seems that one generalization could be drawn, namely, much of the world (based upon the respective samples) is concerned with the impact of technology on society and related development, productivity, education, and quality of life issues. Technology and its impact are being addressed in societies and educational programs worldwide, and frequently technological literacy is being directly or indirectly addressed as well. The world is more than well-aware of the need for technology, the benefits and problems of having technology, and the fact that technology will impact the lives of people in their society. Assuming that this is a valid generalization, it may not be necessary to struggle over an exact definition of technology and technological literacy. There seems to be a broad understanding that technology and literacy go hand in hand to improve the quality of life for people.

This author supports the conclusion that technological literacy is being considered worldwide and addressed regardless of the stage of development of the country. However, it is imperative to remember that the stage of development of a country determines **how** technological literacy is addressed. In the U.S., educators are not only concerned about the knowledge and application of technology, but also with the affective and psychological impact of technology which gets into philosophies and attitudes. Japan, on the other hand, seems to focus on technological literacy from a market share perspective. India is struggling to provide simply the basics for its massive rural populations, and its interests stem from efforts to bring technology into the rural villages—technology long taken for granted by developed nations. Kenya is trying to develop the tourist industry for survival of its people and national treasures, i.e., wildlife. This means bringing in transportation, construction, and communication technologies. And China is trying to attract foreign investment by bringing in industrial production technology. These are all examples of technological literacy issues. The modern industrialized world must remember, however, that before even a very simple technology can be introduced into some of these societies, often developers and educators have to introduce concepts such as time, formal/structured work, acknowledging mistakes without “losing face,” productivity, etc.

Over 50 percent of the world lives in rural villages without access to basics such as water. When considering the population of the world and the fact that the majority of the world lives at a standard lower than the poverty level in the U.S., it seems rather academic to struggle professionally over the definition of technology and technological literacy. One could argue that we might better spend the time improving educational programs that address issues such as reading, writing, arithmetic, and science through technological application so that they make sense to our students and allow for the different styles of learning within our classrooms.

But, for purposes of enhancing international progress and communication, increasing reliability and precision, the emerging definition seems to be one of understanding the role of technology—the appropriate level and use of technology—to impact positively the lives of the people who use it. Therefore, technology and technological literacy become an important issue across the sciences—physical and social alike.

When considering how to address technological literacy on a local educational level, the conceptual framework and philosophies laid out

by Fleming (1987), Dyrenfurth (1987), and Van Poucke and Wansteenkiste (1985) seem to be the most adaptable for curricular and programmatic purposes.

When developing educational programs, it is important to understand that technology's applications are both an integral part of every discipline, yet technology as a construct also maintains its own separate identity. Technology can be used to transcend lines of demarcation and should be used as a catalyst to encourage integration and interdisciplinary participation in attaining educational objectives. Finally, the power of technology as motivator must not be ignored. Students, of any age, when introduced to almost any kind of technology, tend to mobilize their attention and boundless energy—two resources that are key to any nation's future!

CHAPTER FOUR

ECONOMIC PERSPECTIVES ON TECHNOLOGICAL LITERACY

by
David W. Stevens¹

THE ART OF AVOIDING "PAP"

We are passing through a **sound bite** era. Creative expression often dominates thoughtful insight as a criterion for attention. In this chapter, an attempt is made to blend the two—linguistic precision is dispensed with in order to demystify what economists have learned about the importance of technological literacy.

The economist's views can be deciphered by adopting a practical definition of technological literacy: competence in the systematic formulation and testing of hypotheses about different ways to produce desired amenities. Adoption of a systematic approach requires an understanding of agreed-upon principles. Formulation and testing of hypotheses involves practice in problem-solving. Recognition of different ways to produce something requires removal of the blinders of past practice.

Technological literacy is one source of fuel to power the engine of economic growth. Other fuels include natural resources and physical effort, both of which are of diminishing importance. Technological literacy becomes more important as production processes become more complex and interdependent. The benefits to be derived from complexity and interdependence are, in turn, dependent upon technological literacy. Each is cause and effect at the same time. Technological sophistication promotes economic growth, and economic growth demands technical understanding.

¹David Stevens is Visiting Professor, Information Systems Department, University of Maryland Baltimore County, Baltimore, Maryland.

Lester Thurow (1975) uses the following metaphor to describe the economist's challenge:

Imagine watching a chess game without knowing any of the rules of chess. Complicated moves are being made; players are being captured; games are being won. Without being able to ask questions, how long would it take you to deduce the complete rules of chess simply by watching chess games? How many times would you make mistakes, and postulate rules that later observations would disprove? Now imagine a more complicated game in which some of the moves are random events not determined by the explicit rules of the game. Accidents occur. The game is also being played by players who do not always act in accordance with the rules. They make mistakes. In such a game constructing the rule book would be a monumental task. Yet it is just such a game that economists are trying to dissect. What are the rules of the economic game? How are economic prizes distributed? What determines the actions of the individual players? Ultimately, the purpose of knowing the rules of any game is to be able to explain how the game works, to predict the outcome of the game, to play the game better, or, perhaps, to design a better game (pp. vi-vii).

Automobile-, cycle-, and foot-racing have each exhibited dramatic performance improvements as the technology of these sports advanced. U.S. citizens are now engaged in an economic race that will determine what future performance will be achievable. Technological literacy will be an essential determinant of success or failure in this competition.

Think of technological literacy as an objective that can, **but not must**, be chosen. Pursuit of this or any other goal is costly. How do economists assess the relative merits of investing in technological literacy compared with other possible uses of the same resources?

A standard verse in the parental litany children must endure is "abstain from indulgence today to assure a more rewarding tomorrow." Abstinence may then be enforced through a combination of carrots and sticks—"get good grades and you will have driving privileges" or "when you have a test later in the week you cannot go out at night."

The nation's diversion of resources into the development of technological literacy competencies today might be shown to enhance competitiveness tomorrow. A social bonus would then accrue for spending

on future amenities. However, those who would be asked to sacrifice today have no assurance that they will be among tomorrow's beneficiaries. A bird in the hand...! This makes successful abstinence a difficult challenge for educators and legislators.

The remainder of this chapter describes how economists have analyzed technological literacy as an object of choice. What are the rules that determine whether, when and how much literacy is sought? What signals indicate that too little or too much attention has been paid to this objective? What do economists suggest as effective ways to redress any current imbalance that is revealed? How do economists think about who does and who should pay for improvements in technological literacy?

THE ECONOMIC PERSPECTIVE

The Process of Technological Change

Technology is simultaneously enabling and destructive. Technological progress may lower production costs for existing products and services, or it may result in the introduction of entirely new products and services. This reduces the economic viability of enterprises that are unable or unwilling to compete (Cyert & Mowery, 1987).

Why might an enterprise be unable or unwilling to adopt a cost-saving technology or to compete with a new amenity? Three answers are offered here. First, an innovation may be intellectual property that can be protected by patent, copyright, or trade secret statutes (*New York Times*, 1988). The formula for Coca Cola, Michael Jackson's songs, and Stephen Jobs' Next computer are examples of intellectual property. Diffusion of technological knowledge that is protected by any one of these conventions depends upon society's definition of the boundaries of the protection. We often read about the difficulty encountered in enforcing these protections in international markets.

Second, individual firms in an industry are spread along a continuum of technological obsolescence (Flynn, 1988; Leontief & Duchin, 1986). The timing of acceptance of a new technology depends on adoption costs, market standards, and an ability to make informed evaluations of the new technology (Cyert & Mowrey, 1987). Just because a new technology exists does not mean that it will or ought to be adopted. Diffusion of technological knowledge in such unprotected circumstances is uneven. However, predictable stages of maturation are

exhibited. First there is monopoly control by the innovating enterprise, because no one else has had an opportunity to gain experience with the technology; then **make or buy** phases, during which technological literacy either can be **bought** by raiding predecessors who have already adopted the technology or **made** by incurring the costs to offer the required training through one's own auspices; specialized vendors appear when the economies of scale to market trainees with the new skills reaches a necessary level of expected profitability; and ultimately, it appears in the public sector as a **standard** when the technology is considered to be general practice.

One of the great challenges in the 1990s and beyond will be how to contend with the strains that will inevitably accompany the shortening lifecycle of specific technologies. Consider the threat that each of the following poses to traditional ways of doing things: ceramics as a substitute for metals; optical fiber as a substitute for copper wire; and genetic modification as a substitute for fertilizers. Institutional stress will arise because the reduced product or process life-cycle truncates the diffusion stages that were described in the preceding paragraph. There are already indications that some new technologies never reach the public schools because they become obsolete before general adoption even occurs! Cellular communication technology is one example—the Motorola Corporation has been forced to reduce its use of community college training facilities because there is inadequate time to **tool up** the faculties there.

The pressure on public schools can be expected to grow as market **niching** advances. This term refers to the rapidly emerging tendency for small firms to identify a profitable niche, or corner, in a larger market, which can then be met through customized production or service. To the extent that **niching** requires unique technologies, there is unlikely to be a sufficient demand for specific competencies to warrant class size participation by the public sector.

Public schools will be asked to pay much more attention to creating a desire and ability to learn new technologies through one's working lifetime, while perhaps sacrificing immediate competency development on a specific piece of equipment. This will require a dramatic transformation in many schools—away from routine activities and toward more exposure to basic principles of problem solving and teamwork. Industry now expects schools to prepare technologically literate recruits who can learn customized procedures in a short period of time with minimal investment on the company's part.

And third, employee interests must be considered. The term **employee interests** covers a lot of territory. A new technology can either substitute for or complement human skills. In either case employees may be threatened. An innovation that renders a skill obsolete is threatening if a comparable alternative means of earning a livelihood is unavailable. A new technology that extends the responsibilities expected of a worker may also be threatening if the incumbent employee is, or thinks s/he is, ill-prepared to respond to the new challenge.

Technological literacy translates into incumbent security and cooperation; thus the recent introduction in the United States of **pay for learning** compensation practices. These reward workers for what they know, regardless of whether the knowledge is currently being applied on the job.

Since investments in technological literacy divert resources from other uses, there must be some prospect of a subsequent payoff. This requires continuity of the employment relationship, if the employer is expected to absorb at least some of the up-front costs of achieving the desired level of technological literacy (Blakemore, 1987).

Choice as a Dilemma

Recently, there has been a fundamental reversal in the relationship between human beings and natural resources (Clark & Flemings, 1986). Historically, resource limits defined the types and amounts of amenities that could be produced (Office of Technology Assessment, 1988). Today, progress in materials science, technology, and engineering permits resources to be custom designed in response to a specified need. Gene splicing, ceramic-matrix composites, and semiconductors exemplify this reversal.

Technological progress often has profound social consequences, some of which are untoward. The availability of practical cotton harvesting equipment rendered an already poor rural population obsolete virtually overnight. The anticipated introduction of ceramic engine blocks, which require no cooling system, is predicted to have devastating ripple effects on selected industries and communities. Uncoupling from resource endowments jeopardizes already fragile regional economies. Effluents that are a byproduct of new manufacturing processes create new environmental hazards. Plutonium production in Rocky Flats, Colorado may have to be halted in 1990 because no state will accept the resulting radioactive wastes (Lippman, 1989).

An unprecedented range of choice becomes a dilemma when little is known about the ultimate consequences of the decisions that are made. Technological literacy is required to understand both the beneficial and untoward consequences that might be expected to accompany adoption of a new technology.

Sustained technological progress has been characterized as being subject to three conditions: (a) the results must be wanted; (b) the skills to secure these results must be acquired; and (c) access to necessary complementary resources must be assured (McLoughlin, 1986). Technological literacy, its level and distribution, cuts across these three prerequisites for sustained technological progress. The transformation of a hypothetical innovation into a practical reality assumes a technologically literate producer. And, in this age of designer materials, the availability of needed complementary resources is contingent upon technological literacy.

Constraints That Are Not Binding

Technological change is a sufficiently challenging topic for economists that the 1987 Nobel Prize in Economic Science was awarded for fundamental contributions to our understanding of the issue. In his acceptance lecture Robert Solow (1988) stated that

...34 percent of recorded growth (from 1929 through 1982) is credited to 'the growth of knowledge' or technological progress in the narrow sense(;

and that

...the advance of knowledge accounts for 64 percent (of growth per person employed).

Internationally, economists have reached no consensus about the operative constraints on technological progress (Piore, 1987). Management often bemoans the poor qualifications and motivation of many workers. Some blame the schools for a failure to instill a commitment to rigor. Educators divert attention to parental shortcomings and societal permissiveness. Employees protest the introduction of new technologies without consultation with those who are affected by the new process. Consumers decry quality faults in both products and services. Producers respond that buyers are unwilling to pay for higher quality.

This much is clear: although a variety of ideological and institutional forms have been adopted to pursue the common goal of amenity enjoy-

ment internationally, **technological literacy is a uniform determinant of success.**

The Manufacturing Blind Spot

Discussions about the promise of technological progress often focus on manufacturing. This is a mistake for two reasons. First, the ultimate goal of manufacturing is the availability of amenities, so consumption considerations must be addressed as well. Energy-efficient high-rise office buildings with sealed windows were built in response to the energy crisis of the 1970s. Now, a number of alleged losses in productivity are being attributed to the effects of this closed environment on workers.

And second, the benefits to be derived from an application of new technologies to the production of services are often overlooked (Quinn, Baruch & Paquette, 1987). Federal Express identified a market niche in a demand for rapid delivery. This niche, in turn, has been encroached upon by the widespread availability of fax services. Automatic teller machines were introduced by banks in an attempt to reduce dependence upon expensive tellers. Laundry and dry cleaning services are now available through a credit card-controlled remote vending facility.

Concerns that advanced industrial economies will soon be nations of **hamburger-flippers** seemingly fail to reflect an understanding of the interdependencies that exemplify any modern industrial economy. The services sectors are themselves major purchasers of manufactured products, which create both manufacturing and maintenance jobs that require varying levels of technological literacy. Those who derive their livelihood from providing a service also spend a portion of their earnings on manufactured goods.

Admittedly, there has been (and will continue to be) an extraordinary realignment of manufacturing throughout the international economy, but this does not mean that productivity, and therefore incomes, must fall in the nations that exhibit increasing concentrations of employment in services (Malecki, 1983; Amin & Goddard, 1986). Many of these services (e.g., in the health care and financial sectors) are technology-intensive, which means that individual workers can exhibit high productivity and continue to enjoy high earnings levels; but only if they are technologically literate.

While manufacturing is a blind spot in some respects, it also offers compelling examples of the range of opportunities for innovation that await creative insights. Christmas card images of horse-drawn sledges

collecting maple syrup in the woods of Vermont during the late winter are succumbing to miles of plastic tubing attaching the trees to vacuum pumps that literally suck the sap from the trees into a reverse-osmosis machine!

THE PROCESS OF TECHNOLOGICAL CHANGE

Options: Invest Today or Wait Until Tomorrow?

Individually, and collectively, we have **windows of opportunity**—times when a choice must be made whether to act or defer to a later date. The arrival of new acronyms traces the learning curve: Advanced Manufacturing Technology (AMT); Flexible Manufacturing Systems (FMS); and Computer Integrated Manufacturing (CIM) (Braden, 1987-88; Mark, 1987).

How much technological literacy is enough, when is it needed, and in whom should it be embodied? Much has been written about the relative paucity of effort to achieve technological literacy in the United States (Obey & Sarbanes, 1986). Short-sightedness and a selfish indulgence in current amenities are offered as explanations why little response is observed to what some see as a challenge, or even a threat.

A cyclical issue is reemerging in the United States that promises to revise the answers that have been given recently to questions of how much technological literacy, for whom, and when. This issue is labor market shortages.

Self Interest Works (Almost) Every Time

"When the going gets tough, the tough get going" is an apt phrase to describe the response of many enterprises to new waves of international competition. Historical throw-away personnel practices of recurring layoffs followed by hiring of less expensive replacements are disappearing. In their place several new patterns of human resource deployment are observed. In many cases production activities that had been performed internally were contracted out to vendors. A General Motors assembly plant in Wentzville, Missouri that was considered to be state-of-the-art when it opened less than ten years ago is now considered to be poorly designed because so many component manufacturing activities have been contracted to external vendors.

Temporary help agencies are called upon to provide a wide range of services in both the manufacturing and services sectors. In some cases employees are leased on a continuous full- or part-time basis. This transfers personnel paperwork responsibilities to the temporary help agency. It also eases decisions to terminate the use of the employee's services if market conditions warrant.

In either the vendor contracting or temporary help service agency approach, employees lose equity in the performance of the "mother" enterprise. This removes one of the obvious incentives for self-improvement and motivation (Osterman, 1987; Belous, 1989).

This slim-and-trim personnel policy is designed consciously to minimize a firm's commitments to individual employees, so that maximum flexibility is maintained to respond to competitive market forces. These practices are a successful insulation against downside risk—i.e., a vulnerability to costly commitments that extend beyond a time-horizon over which production levels can be forecast with confidence. However, they impose a cost of their own: neither the firm nor the employees are willing to invest as much in training in the absence of a reciprocal commitment to continuous employment (Bishop, 1989; Commission on Workforce Quality and Labor Market Efficiency, 1989).

This realignment of reciprocal commitments between workers and firms will coincide with the following five demographic facts in the United States (Johnson & Packer, 1987):

- The population and the workforce will grow more slowly than at any time since the 1930s.
- The average age of the population and the workforce will rise, and the pool of young workers entering the labor market will shrink.
- More women will enter the workforce.
- Minorities will be a larger share of new entrants into the labor force.
- Immigrants will represent the largest share of the increase in the population and the workforce since the first World War.

Historically, each of these demographic facts would suggest a dilution of technological literacy. It is therefore reasonable to assume that two new coalitions will emerge. On the one hand, industry will seek public funds to bolster productivity without incurring the attendant costs that would otherwise threaten competitiveness (Stevens, 1989;

Creticos & Sheets, 1988). On the other hand, many firms will find it necessary to reestablish some type of bond with a wider spectrum of employees to secure the productivity that will be necessary to remain economically viable in the international economy.

What can be expected during the 1990s in the United States is a very uneven but pervasive realignment of public-private and employer-employee coalitions. Technological literacy will not rise as a uniform tide level, at least not through market forces alone.

The Compelling Public Interest

Enterprises invest in technological literacy when they expect to be able to recoup a payoff on this investment through subsequent employment continuity. Individuals are motivated by the same anticipation, although employment continuity need not be restricted to a single enterprise if the literacy is transferable among firms. Both firms and individuals may be unable or unwilling to devote a socially optimal level of investment to technological literacy. The same can be said for municipalities and states in the United States. Why? Because potential mobility threatens the certainty of the payoff period that is necessary to make the optimal level of investment attractive. This leaves the federal government as the sole party with a compelling responsibility to represent the national interest in competitiveness.

One manifestation of Congressional commitment to technological literacy, albeit an oblique one, is continuing appropriations for the activities of the National Occupational Information Coordinating Committee. This Committee is charged with overseeing efforts to develop accessible career information delivery systems and occupational information systems for counseling and program planning uses (National Occupational Information Coordinating Committee, 1988). If our intelligence about emerging technologies is not accurate and timely, then the public interest is unlikely to be well served (Stevens, 1987).

At a micro level the public-sector choice is between a passive acceptance of the market's underinvestment in technological literacy through independent enterprise and individual decisions, or a public investment strategy that complements these private choices. In principle, a public investment today can promote higher productivity, improved competitiveness, and escalating private investments in technological literacy tomorrow. The Research Triangle Institute in North

Carolina is often cited as an early example of a state investment that has reaped a rich reward in the form of new industries and employment opportunities. Many states are now emulating this early initiative in the form of higher education compacts with private sector partners. A danger lurks in the shadows of this tactic—once spending coalitions are formed they constitute an effective lobby for perpetuation.

At the macro level the compelling public interest in technological literacy, which exceeds that of selfish private interests, is reflected in potential savings to the tax paying public—ranging from welfare and food stamps through mental health, criminal justice, and housing subsidies. There is a direct link between employability and a reduced probability of dependency. Confidence that creative talent and hard work will be recognized and rewarded is a powerful weapon against dependency.

Thresholds and Ceilings

How, then, does an economist answer the how much, for whom, and when questions about technological literacy? Employers who are subjected to intense competitive pressures to control costs will invest only what and when they are compelled to by market forces, and they will always be alert to opportunities to shift the burden of achieving and maintaining the necessary level of technological literacy to third parties (e.g., other employers, state legislatures, or the Congress) (Sheets & Stevens, 1989).

Employers who are sheltered from competitive forces may enjoy a profitability cushion, which permits them to indulge in a higher level of internal resource commitment to technological literacy. However, precisely because they are not subject to intense competition, there is no necessity that they devote reserves to this use. Their actual behavior will be a function, in part, of what is called market **contestability** (i.e., the extent to which the firm's market is subject to a threat of competition).

Individuals are unlikely to adopt a far-sighted investment strategy, particularly in the absence of convincing evidence that future vulnerability to obsolescence can be predicted in a reliable manner. Such evidence has not been forthcoming to date, despite often repeated but poorly documented assertions about how many different jobs an average individual can expect to hold over a working lifetime. The most recent evidence indicates that an overwhelming share of workers who change occupations do so voluntarily (Markey & Parks, 1989).

There is a tantalizing hypothetical question here: how many workers would like to change occupations, but are prevented from doing so by a real or imagined inability to meet employer expectations (i.e., an ability to learn new competencies quickly and at little expense to the new employer)? There is no information available to answer this question. Yet, this is precisely the information that is needed to build a compelling case for a higher level of investment in technological literacy!

Who is left to turn to, if neither employers nor individuals can be expected to respond to current market signals? Government. But members of Congress, state legislators, and local school board members are subject to the same absence of convincing evidence about future technological literacy requirements as are personnel managers and lay people. However, there is an important difference between private and public agents—the former are expected to act selfishly, while the latter are expected to represent broader constituent interests.

To the extent that a sense of trust can be established among the members of a society, a promise of future access to technological renewal can be substituted partially for an immediate defensive commitment of resources in anticipation of possible obsolescence in the future (Ouchi, 1984). Contingency spending can be a serious drag on the nation's current and future productivity, as Congressional deliberations over defense spending illustrate.

The substitution of future commitments for present obligations offers an opportunity to reallocate today's resources to bolster immediate competitiveness. Today's investments in technological literacy can then be focused on known requirements to satisfy current production needs. Unfortunately, an opposite trend exists in the United States—escalating academic requirements at the high school level are forcing reductions in at least some technology-based curricula.

An intergenerational bond does not exist in the United States today. Adult access to a renewal of productive potential is extremely uneven and generally stigmatized. There is an implicit attitude that everyone has an opportunity to acquire competencies at public expense as a youth; so subsequent dysfunction is the victim's own fault. Widespread awareness of the extent of adult literacy deficiencies has created no groundswell of commitment to break down this barrier to individual and collective advancement. Few adults are offered an opportunity to sustain themselves and their dependents at an accustomed level of comfort while they attempt to renew their skills.

SUMMARY: TOWARD A PRACTICAL APPROACH FOR DECIDING HOW MUCH TO INVEST IN TECHNOLOGICAL LITERACY

A sensible approach to investing in technological literacy in the United States today would recognize complementary roles for public and private agents. Public support in the pursuit of private competitiveness (i.e., profitability) would be acknowledged in the form of a reciprocal willingness by **winner**s (both enterprises and individuals) to contribute to the subsequent renewal of **loser**s. Public investment is necessary because some of the payoff to higher levels of technological literacy cannot be captured by individual businesses or employees.

This reciprocal willingness could be expressed in many ways: tax payments that are earmarked for this purpose; voluntary contributions to schools of the donor's choice; or a subsidized offering of the renewal through one's own organization, among other possible approaches.

Recall the definition of technological literacy that was stated at the beginning of this chapter: competence in the systematic formulation and testing of hypotheses about different ways to produce desired amenities. All students, regardless of their subsequent intended pursuits, would benefit from more attention to the development of these skills.

Today, most students are given well defined problem assignments and they are told to find the single correct answer. Few students are challenged to identify a problem on their own, to consider alternative solutions to this problem, and to select a preferred answer based on criteria that the student chooses. More exposure to technological problem-solving could be introduced in virtually any subject area. Historical case studies of both purposeful and accidental discovery could sensitize students to the varied ways in which technological breakthroughs occur. The study of sociology and psychology could include examination of the individual and collective human consequences of technological change. This would prepare students to have an appreciation for the personal gains and losses that accompany economic growth. Consider how a single invention—the traffic light—could be used as the basis for study in any disciplinary setting. Higher levels of investment in technological literacy can easily be accommodated within current curricular offerings.

The rewards for technological literacy are now distributed quite unevenly in the United States (Levy, 1987; Markusen, Hall &

Glasmeier, 1986). Few of us believe that those who stumble or fall in the race for amenities are simply victims of their own previous choices. Invention has been, and will continue to be, a cruel destroyer of many people's efforts and aspirations. It is our common obligation to assure sufficient access to renewal that they, and therefore we, can enjoy the amenities that flow from their renewal. An appropriate investment strategy in technological literacy is one way to achieve this goal.

CHAPTER FIVE

LABOR, PRIVATE SECTOR, AND GOVERNMENTAL PERSPECTIVES ON TECHNOLOGICAL LITERACY¹

by
James L. Barnes²
Thomas L. Erekson³

Increasingly of late, Americans have come to the realization that productivity and international competitiveness are key to the maintenance of the quality of life so many have come to expect. Central to the overall competitiveness of our nation are the cooperative efforts of labor, business, industry, and government. This chapter presents the perspectives each of these sectors holds with respect to the implications of technological change and technological literacy.

THE ECONOMY: LABOR AND PRIVATE SECTOR

Governments establish laws that govern the monetary and economic systems of nations. Thus, one of the most visible outcomes of technology is economic—technology provides economic strength to people and communities. Teich (1990), when speaking about the United States, stated that the "strong competitive position of U.S. industry, particu-

¹This chapter presents a synthesis of independently produced works by the listed authors. To better address the yearbook committee's objectives, these individual submissions were integrated to present the non-education's sector's perspectives as a coherent whole. Dennis Chamot, Executive Assistant to the President, AFL-CIO, Washington, D.C. contributed the labor sections of this chapter.

²James L. Barnes, who authored the private sector sections of this chapter, is Assistant Professor, Department of Business and Industrial Education, Eastern Michigan University, Ypsilanti, Michigan.

³Thomas Erekson, who authored the government sections of this chapter, is Professor and Head, Department of Industrial, Technological and Occupational Education, University of Maryland, College Park, Maryland.

larly technology-based industry, relative to other nations, has been one of the major sources of this country's wealth and its worldwide political and economic influence" (p. 299). However, Teich also noted, that the competitive position of the U.S. has begun to slip in the past decade as evidenced by losses in areas such as auto production, and consumer electronics, resulting in a trade deficit. This slippage has implications of a declining standard of living.

The Commission on Industrial Competitiveness (Young, 1990) identified one of the four major causes for the decline of American competitiveness as "shortcomings in our commercialization of new technology" (p. 300). Young went on to describe how U.S. industry could improve its competitiveness through better "development and deployment of technology." This discussion described a strong relationship between technology and the economic strength of individuals and the nation. Furthermore, he referred to the link between technology and productivity as "the cornerstone of competitiveness."

The success of local communities in revitalizing their economies through technology-based reindustrialization has shown relationships between technology and economic strength. Flynn (1988) provides a case study of the economic benefits of technological reindustrialization in Massachusetts. In Lowell, cooperation between government and the private sector provided the policies and venture capital to reindustrialize with technology-based industries. The result was an increased employment base and an increased standard of living. This strengthened local economy, with good jobs, has become the envy of other communities. As a result, many communities have established Economic Development Commissions to attract new, technology-based industries that will revitalize their economies.

Technological literacy among adults is important off the job, as well. We are increasingly faced with political and public policy questions that have a strong scientific or technological basis. Depletion of the ozone layer; the problems of exposure to toxic chemicals in and outside the workplace; safety of food additives; the Star Wars defense system; and the safety of genetically engineered organisms are but some of these issues. Enhanced understanding of science and technology is essential for people to exercise properly their rights and obligations as citizens in today's technology-intensive existence.

Our Changing World

The American labor movement has long been interested in promoting general education. Trade unions were early strong supporters of free public schools and they continue to press for improvements in our educational system. Unions also have been in the forefront of vocational and job training efforts, particularly in the skilled trades.

A relatively recent phenomenon that has made the situation more complex has been the growth of the white collar workforce. White collar workers began to outnumber blue collar workers in the United States in the mid-1950s, and today account for about 55% of the entire American labor force. This is the first time in all of history that people who work with their minds outnumber people who work mainly with their hands, and the trend is continuing.

Today labor is no longer a commodity. Work is being transformed by technology—technology invented by people, of course—and by fundamental changes in the structure and operation of our economy. The new emphasis is on brainpower—individuals have to solve problems, make decisions and analyze data in a hotly contested international marketplace. To do that they have to have skills (*Magazine*, January 19, 1989).

The resources of the information age do not come from the ground as they did in the industrial age, instead, they come from the mind. Today, positioning and power in the global economy are based on the power of ideas, information, and productivity. The skills defined by the industrial age were defined by the ability to memorize. Today, the skills needed are defined by the ability to think; analyze problems; make decisions; and access, manage, and control information.

Technology has caused the world to shrink and information networks have linked the global economy. With this, interactions in the global economy have become very complex. Corporate power and competitive shifts in manufacturing and other technologies through the advances of technology and their transfer have further complicated the global market. What is appropriate technology for one nation or culture may not be suitable for another. What guarantee does any nation have that it will remain competitive in the global marketplace? Will the so-called advanced post-industrial or cybernetic nations become the developing nations of technology of the 21st Century? One factor is

likely to hold true: global market position, i.e., dominances, will go to the nation with the best, most technologically literate industrious workforce.

In order for corporations and/or economies to gain and sustain a competitive edge, they must have a workforce which embodies four primary characteristics: (a) speed, (b) innovation, (c) diversity, and (d) information. This places emphasis on the identification and analysis of future workforce skills needed and the type of work people will do. The true focus, then, is not on the product, but on the people who produce the product.

This concept was supported by Goor (October 19, 1988), the President of Cooper Tire and Rubber Company, when he outlined his **formula for the future** for an individual or corporation. He suggested that the individual or corporation must possess (a) logic, (b) emotion, and (c) character. Logic is the basis for scientific thought and investigation. Emotion is heart, compassion, understanding, and empathy. Character is the balancing factor between logic and emotion.

The resultant of this is what John Young (September 28, 1988), President and CEO of Hewlett-Packard, identified as the ability to commercialize technology, not just come up with the scientific breakthroughs, technology developments, or innovative products. Simply, this means to use the technology available to capture the market and generate major returns on U.S. innovations.

In order for the corporation to use the available technology to its best advantage, the workforce must be literate in the application of that technology. Technology transfers have shifted industrial production drastically in the last quarter of a century. During that time over 32,000 technology agreements have been made with Japanese firms. In 1970 the United States controlled 100 percent of the domestic consumer electronics market; today the U.S. only controls five percent of that market. The United States pioneered semiconductor technology; yet today controls only 30 percent of that market. Twenty years ago 16 percent of the patents issued by the U.S. Patent Office were foreign; today more than 40 percent of the patents issued by that office are foreign (Young, September, 28, 1988 & Sculley, February 2, 1989).

The question to ask, then, is: "What will be the advanced technologies with which this future workforce will have to work?" One attempt to identify them was done by the Science and Technology Agency (1985). Their summary is highlighted in Figure 5-1.

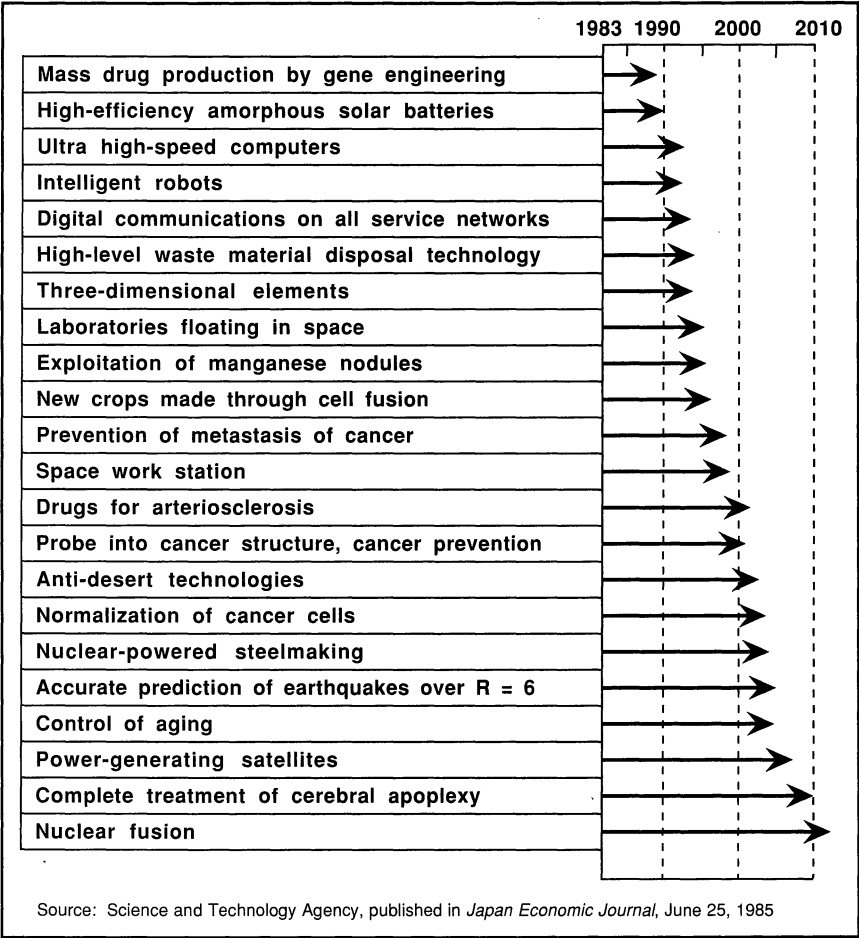


Figure 5-1. Advanced technologies in 2010 projected by 2,000 experts.

E. Ehrlich, Vice-President and Economic Analyst for the Unisys Corporation suggests that now and in the future the ability for one to monitor computer screens and understand abstractly what is going on the screen will be the way one works. Employers will demand an ability to understand abstract data and to effectively communicate it to others.

A foreman can stand behind a worker on an assembly line and make sure that person drops a 53-pound bucket seat into the chassis of a Ford Thunderbird every 24 seconds. But what do you do when that foreman has to supervise a worker who is looking at a display, at a CRT, to oversee a process depicted by a computer? How do you supervise thought (Ehrlich, June 14, 1989)?

Translating this type of philosophy into the corporate world means breaking many years of tradition. The corporate world has been traditionally labor-intensive, product-oriented; not mind-intensive, process oriented.

For over 200 years, much of the work ethic was based on working for someone else, with accomplishment measured by someone else's standards. Work was supervised primarily through a centralized system. More often than not, work emphasized the physical, not the mind. Workers were trained to perform the specific skills required for repetitive work.

In contrast, the future workplace will be primarily decentralized. Entrepreneurs and intrapreneurs will be key figures in the corporate structure. Accomplishments will be measured by the individual worker's standards of self-satisfaction. "Already, one of five people switches jobs each year, one of 10 switches careers, and 33 percent of all jobs today and tomorrow will be obsolete by 1992" (Hallett, 1987, p. 15). The workplace of today and tomorrow will be built on the team concept, with group work, quality circles, task forces, and more.

Workforce Trends⁴

More than ninety percent of the workforce in Revolutionary times was engaged in farming and agriculture. The work was done by hand with simple tools, with animals supplying additional power for heavy

⁴More details about labor history and the impact of technology on the workplace may be found in R. B. Morris (Ed.), (1976), *The U.S. Department of Labor History of the American Worker*, Washington, DC: U.S. Government Printing Office, and in D. Chamot and J. N. Baggett (Eds.), (1979), *Silicon, Satellites and Robots: The Impacts of Technological Change on the Workplace*, Washington, DC: Department for Professional Employees, AFL-CIO.

jobs. In the nineteenth century, agriculture technology began to improve rapidly. Various machines were developed, along with new strains of plants, improved breeds of livestock, and better fertilizers. The productivity of workers and agricultural enterprises soared due to the advancing technologies of those times.

A consequence of rapidly increasing productivity was a reduced need for labor; each farmer could produce much more than before, requiring fewer people to operate the farms. As a result, quite a few farmers and/or their children sought work elsewhere.

Particularly during the second half of the nineteenth century and the early part of the twentieth century, the growth areas of the economy were manufacturing (factories) and construction. Farmwork continued to decline as a fraction of the overall expanding workforce and, conversely, blue collar, industrial workers increased in proportion.

Since the beginning of the Industrial Revolution, the success of manufacturing in a capitalistic society was dependent upon the constant improvement of machines and work organization. New technologies were continuously developed and introduced into the various parts of the manufacturing sector. Factories became ever more productive: from steam power to electricity; from wood, cloth, and iron to steel, plastics, and ceramics; and from individual craftwork to interchangeable parts and assembly lines.

Today, however, America is experiencing a new economic situation. While employment of blue collar workers is stagnating, the **value** of manufacturing and construction, in dollar terms, continues to grow, and the volume of output is still increasing. What all this means is that both the size and productivity of manufacturing is continuing to increase, although fewer people are required to produce the products. Increasing imports contribute to this situation in that imported products do not require any domestic labor. Thus, they remove employment opportunities. Modern technological developments such as computers, robots, satellite communications, and new materials also reduce the labor content of what is manufactured in this country.

At present, knowledge and technology is estimated to double every two and one-half years. This means that 90 percent of the information that will be available to the workforce in 2007 has yet to be created (Hallett, 1987, p. 48). The dominant force driving this change is an exponential advance of technology. Logically then, the substance of the future workforce training and retraining must be in step with the everchanging technological base of our world.

Many of the nation's leading workforce observers: e.g., the Hudson Institute (Johnston & Packer, 1987); Hallett, 1987; Levitan, 1987; AFL-CIO Committee on the Evolution of Work, 1983; National Alliance of Business, 1986; and Cetron, Rocha, & Luckins, 1988 strongly agree on the key trends and the characteristics necessary for a technologically literate workforce in the future. Among these are:

- The increasingly complex workshop will demand higher levels of literacy.

Jobs will be defined more broadly and will include more interrelated tasks. Flexibility will increase in importance. More discretion will be delegated to lower levels of the organization, where information and the expertise exist. More employees and their representatives will be involved in more activities that affect them and require their support and cooperation.

- The workforce itself will change dramatically in the future.

By the year 2000, workers aged between 35-47 and 48-53 will increase to 38 percent and 67 percent, respectively. Conversely, workers aged 16-24 and 25-29 will decline by 8 percent and 13 percent; women will constitute 67 percent of all new workers; and more than 15 percent of the total workforce will be Black or Hispanic.

- The advance of technology will create many new problems to solve.

The abuse of stored and transmitted information will become a global problem. Advances in chemical, biological, biotechnical, and medical research will create numerous social, ethical, and moral issues to resolve. And, new materials will require new environmental protection measures.

- Essentially all work in the year 2007 will be new.

Forecasters and demographers indicate increases in computer, electronic, service, and health care jobs. Many of these will be significantly different than such work today.

- Changes in education and training will occur by 2000.

The need to retrain will continue to escalate toward and into the 21st century. Corporations will play a more significant role in training and education. Schools will have to educate both children and adults.

Schools will continue to play a crucial long-term role because of the costs associated with retraining the existing workforce and educating those of the entering workforce who are deficient in the basic skills.

Apple Computer's Sculley believes one possible solution is through the use of technology at the level of government and business in schools and through a vast networking system (February 2, 1989).

Technology and Job Loss Fears

One subject that must be addressed **head on** is the potential for modern technologies to be used specifically to eliminate jobs. In the past, new developments spread slowly, and usually only in one industry at a time. This pattern provided time for the economy to adjust. Of course, severe problems existed, but typically they were localized, and relatively temporary in nature.

Modern technologies alter this picture. Today, their rapid introduction occurs simultaneously in many industries and in many kinds of jobs. This alters the entire change and accommodation cycle drastically and there is significant potential for increased disruption.

Changes in the Nature of Work

In the early stages of the Industrial Revolution, as complex machinery powered by steam or electricity became commonplace, the actual job skills demanded of many did not necessarily become more complex. In fact, the rationalization of factory work, i.e., the dividing of complex operations into a series of simpler, more routine tasks often led to **deskilling**, the elimination of complex skills acquired by craftsmen through years of apprenticeship training.

Today's workplace is far different, whether it be a factory or an office.⁵ Computers and related technologies are permitting a redefinition of jobs on a massive scale, calling not only for new skills, but also requiring broader knowledge in order to take full advantage of opportunities that may develop.

A few years ago, the Swedish auto maker, Volvo, decided to try a new approach, for which they designed a completely new factory. This one was based upon a concept of work groups. Instead of each worker endlessly repeating a single, short, simple task, small groups of work-

⁵See Chamot, 1988, *The Industrial Revolution and the Information Revolution: Is Social Upheaval Inevitable?* by Dennis Chamot, *Toqueville Research Parallels*, No. 6, Toqueville Asset Management Corporation, New York, New York, April 1988. This paper was reprinted in its entirety in *Manufacturing Competitiveness Frontiers*, vol. 12, no. 7, pp. 1-9, Manufacturing Productivity Center, Illinois Institute of Technology, Chicago, Illinois, July 1988.

ers built entire subassemblies or subsystems. There was much more variety, and more of an opportunity for the workers to feel a sense of satisfaction and accomplishment. In order to get this new organization to function, Volvo engineers had to redesign the plant, and much of the transport, communications, and assembly equipment. While the products of this factory were essentially the same as those of factories with standard assembly lines, the internal design was very different; and the jobs were very different, as well. Instead of "designing out" the people and striving for a fully automatic factory, the Swedes chose to humanize the workplace. The experiment has been very successful, both in human and commercial terms.

Most unions today are concerned about potential job loss due to new workplace technologies. For example, Morton Bahr, president of the Communications Workers of America, noted that, "high technology will never create the same level of jobs that will be eliminated" (AFL-CIO, 1988, p. 10). In the same vein, William Lucy, Secretary-Treasurer of the American Federation of State, County and Municipal Employees, has said, "We must take control of the technological agenda. We must make human resources as great a concern in that agenda as the care and feeding of machines...What we need, and must pursue, is no less than a total national commitment to life-time worker training and retraining, to a system that gives workers the right to be ready for available jobs, to a system that parallels our existing system of public education" (AFL-CIO, 1988, p. 8).

The United States has a very diverse adult population and workforce with education that ranges from high school dropouts to holders of Ph.D.s. and professional degrees. The workforce includes people who are deficient in basic language skills as well as technological concepts, but also people who **design** extremely sophisticated technology-based systems.

On the Job Needs for Technological Literacy

Technological literacy must follow basic literacy. For a disturbingly large fraction of our adult population, poor reading, reasoning, and mathematical skills leave them unprepared for all but the simplest jobs in our increasingly complex economy. Unions have established, through the collective bargaining process, education programs to deal with the education and training needs of their members. This is true of unions with diverse memberships, such as the United Auto Workers;

the United Steelworkers, with primarily blue collar memberships; and the Communications Workers of America and the American Federation of State, County and Municipal Workers, with many white collar members.

Technological literacy is becoming increasingly important as jobs become more complex as a result of more widespread use of technologies as well as job enlargement policies. In today's workplace, a lack of technological literacy means a lack of control. If important decisions are made by management because workers are not able to participate, they may be based on assumptions and desires that are not in the best interests of the people who will be performing the work. In other words, the employees and their representatives need to be technologically literate in order to have a chance to influence the key decisions.

For example, while it is not necessary to know very much about the intricacies of computer programming, most office workers should learn about the principles of computer operation. Understanding such things as the difference between working memory temporarily available while the computer is on, and permanent storage on floppy or hard disks, or understanding the role of interchangeable software, is crucial for the individual to feel comfortable with the system and to realize the full potential of the job.

From labor's perspective, it is also necessary for employee representatives, for union stewards and other officials, to be aware of the technologies and their implications. A key, and legitimate, function of unions is to protect their members from improper or arbitrary applications of such technology. Increasingly, this includes: a concern for proper training of employees when new technologies are introduced; a desire to see that individual jobs are improved by new technologies, not routinized or made more stressful; a need to protect employment levels among loyal employees when technological changes make it easier, but not essential, for jobs to be moved to other locations; and in today's climate, to be prepared in general to participate in the process of seeing how new technologies can be used to improve the health of the enterprise while also protecting the needs of current employees. To accomplish any of these things requires a broad understanding of modern technologies.

If the design of equipment, software, and work organization is performed by engineers and managers, why do other workers need to have any great knowledge and understanding of technology? There are

at least two fundamental reasons. The first, of course, is to be prepared for the jobs of the future. As illustrated above, many jobs are becoming more complex. They involve the use of more sophisticated systems which may involve concepts and methods of operation that are not intuitively based on experiences from everyday life. And the second need for increased technological literacy is to challenge the assumption implicit in the first sentence of this paragraph.

GOVERNMENT PERSPECTIVE

Civil Sector

Governments are social institutions that are established to serve and protect the citizens. To serve, governments strive to improve the standard of living and the quality of life for the citizens. This includes providing for economic strength and development, providing appropriate social services, including education, and protecting the country. To protect, governments provide laws, with enforcement mechanisms, that protect the rights of the citizens, and governments provide military forces to ensure the protection of the citizens from other nations.

Through serving, controlling, and protecting, governments gain power. Governmental power can be used to control the citizens of the nation, and the citizens of other nations, depending upon how the powers are administered. Likewise, the government's technology policies and information about technology and its promises and impacts, can provide power for those who can control it. Thus, in a free enterprise economy, entrepreneurs develop and exploit (control) technology for profit. However, government regulates (controls) technology to protect the public interest (DeVore, 1980).

Technology alone is not a panacea—governmental leaders must have a high level of technological literacy and access to accurate advice if they expect to properly employ the potential offered by technology for the benefit of the citizens. It is imperative that technology policies be developed from a knowledge base that looks to the future. DeVore (1980) emphasized this point in stating that "ignorance cannot be used as an excuse for making decisions detrimental to the long-term survival of society" (p. 337). **Literacy** is the opposite of ignorance and literacy is imperative when developing effective technology policies.

The perspective of local, state, and federal governments concerning technological literacy is greatly influenced by the people who are elected to government office and their staff. The majority of elected officials in the U.S. Congress, and most state legislatures, come from the law profession (DeVore, 1980). In law, decisions are based on precedents, in effect past decisions, which may not be an appropriate base for decision making when issues deal with the unknown future (DeVore, 1980). Relatively few elected officials have backgrounds in technological areas. Thus, the perspectives of science, engineering and technology, and literacy about technology, is shaded by the background and experience base of each elected official.

The level of technological literacy of government officials is a major concern when people who are not technologically literate are establishing (or not establishing) policies and developing regulations that impact technology and its uses. As citizens, in addition to our responsibility to elect government officials who understand technology and are literate about its uses and impact, we need to encourage them to hire knowledgeable and ethical staff. If government personnel do not attain an appropriate level of technological literacy, or gain insight by seeking advice from technologically literate individuals and groups, there is clearly significant potential for disaster. Environmental pollution, hazardous waste, and other potentially disastrous impacts can result when laws are passed, or not passed, that affect technology and its utilization throughout the country.

Social Service

Governments also seek to exploit technology in providing social services for the citizens. Assuring quality health care and education are examples of technology-dependent social services that improve the quality of life. Governments establish policies and provide funds to improve social services. For example, in the area of health care, the United States government spent millions of dollars in research and development to produce a vaccine for polio. Likewise, today many governments have funded massive research and development efforts to produce medications to prevent and overcome AIDS (Acquired Immune Deficiency Syndrome). These efforts in the development of health technologies are intended to protect the citizens from deadly disease.

Education is a social service that has direct ties to economic strength and quality of life. Thus, governments seek to provide the highest

quality of education possible. Education has become ever more important when governments want to exploit new technologies to improve the standard of living. Exploitation of sophisticated technologies requires a workforce that has a high level of technological literacy.

Technology, and education about technology, is a topic that has great promise for improving life and work in our society. As a result, several educational initiatives to improve technological literacy have been established. At the state level, several state guides for technology education have been developed and used to redesign the curriculum. Furthermore, several states have mandated technology education for all students at the middle school level. The intent of these initiatives has been to improve the technological literacy of students.

The federal government has also enacted legislation to promote technological literacy. The Omnibus Trade and Competitiveness Act of 1988 included a section to fund technology education programs. The purpose of this section was stated as:

To assist education agencies and institutions in developing a technologically literate population through instructional programs in technology education (Chapter 2, Section 6111).

This legislation is but one of several U.S. federal laws that encourage and promote education programs to improve technological literacy.

Office of Technology Assessment

It is difficult for any one person to be knowledgeable and literate about all technologies. Realizing their need for access to accurate information about technology and its impacts, the U.S. Congress established the Office of Technology Assessment (OTA) in 1972 to perform analytical work. The basic function of OTA is to help the U.S. Congress anticipate and plan for the consequences of technological changes and to examine the ways, both expected and unexpected, in which technology will affect citizens' lives in this nation and throughout the world. The assessment of technology calls for exploration of the physical, biological, economic, social, and political impacts that result from the applications of scientific knowledge and technological applications.

The Office of Technology Assessment has done studies in several areas including: energy and materials; industry, technology, and employment; international security and commerce; biological research; food and renewable resources; health; communication and information technology; oceans and environment; and science, transportation, and

innovation. Establishing the OTA was a positive policy step to assure an appropriate level of technological literacy for members of the U.S. Congress as they establish policies and laws that impact technology and its uses in this country and transfer to other nations.

Military Sector

The use of weapon and communication technologies provides governments with military power and dominance. For example, the development and deployment of nuclear weapons by the United States brought an end to World War II. In addition, the control of nuclear weapon technology placed the United States in the unique position of world power leader after World War II. However, when the U.S.S.R. gained the technological capability to manufacture and deploy nuclear weapons, an escalation of nuclear technology development took place that assured that neither nation would be able to control the other.

The military uses technological hardware and software to establish the offensive and defensive capabilities of a nation. The U.S. military spends millions of dollars on research and development to improve the defense capabilities of this nation. As the hardware and software utilized in military operations have become more sophisticated, it has required the military to look at new approaches to training their forces. In effect, the soldier of the future will need to have a broad base of technological literacy to enable him or her to utilize the sophisticated military hardware and software.

In its attempt to constantly improve technology, the military needs to test, under conditions that approximate reality, the hardware and software that it has developed. When skirmishes and military confrontation take place, U.S. military personnel gather data about the use of weapons technology. For example, Israel provided United States military technology to their armed forces. After they experienced a real skirmish with countries that use Soviet military technology, the United States collected data to determine the effectiveness of our offensive and defensive technology. Technological superiority, including technological literacy, is a major goal for the military.

For many years the military has trained its personnel in very narrow, skill-specific technical aspects required to maintain the hardware, software, and defense capabilities. This very narrow training is very costly to the government and, to some extent, its narrowness discouraged people from leaving the armed forces once they have

received the training. However, as the hardware and software have become more sophisticated, the military has had to look at a much broader base of education for its armed forces—in effect assuring that military personnel have a broad-based technology education.

ORGANIZING THE STUDY OF TECHNOLOGY

It is imperative that the study of technology be organized in a curriculum model via manageable components that are universal to a holistic study of technology. It must also be organized in such a manner to allow for the transfer of knowledge from one technology or problem to others.

To help facilitate this type of study of technology it is critical that one utilize the corporate world. Through cooperative partnerships in the study of technology between corporations and educational institutions, technological literacy can be developed.

Human Capabilities Needed for the Future

Townley (January 27, 1989) reported an American Society for Training and Development estimate that productivity losses caused by a poorly educated workforce, combined with remedial training programs, cost U.S. businesses approximately \$25 billion per year. For example, about one-third of Polaroid's hourly workers are enrolled in a company-sponsored elementary reading and writing program. A sharp critic of such programs, Kearns, the CEO of Xerox calls this "doing the school's product recall work."

At present, there are an estimated 27 million functionally illiterate adults in the U.S. There are another 46 million American adults who can be considered marginally illiterate. The public schools are generating approximately 700,000 new functionally illiterates per year, and an additional 700,000 drop out each year. This raises great concern that a high percentage of the potential workforce of the future may not have the skills to find a job or the flexibility to meet the challenges of the changing job requirements (Townley, January 27, 1989).

The joint study of the National Academy of Science, National Research Council, and Manufacturing Studies Board, *Toward a New Era in Manufacturing*, highlighted the key human capabilities necessary for tomorrow's workforce. According to the report, the future worker

will need to possess the ability to think critically and creatively using innovative problem-solving techniques. The worker will also need good communication skills and the ability to work well within groups. To support and enhance these capabilities in the worker, management will have to be more flexible, humane, and innovative (1986).

The call for reform in the study of technology and its curricula is evident. This is based on the way one will have to function in the 21st century in order to survive. Future trends and forecasts do not leave much room for the status quo or traditional study of technology. Key corporate leaders emphasize the need for change in order to produce a more technologically literate citizen for tomorrow's workplace.

Workforce Skills/Competencies for the Future

The preponderance of the literature supports five generalizable or basic sets of skills to produce a technologically literate future workforce: (a) communications, (b) problem solving, (c) critical thinking, (d) creative thinking, and (e) teamwork/group work. In addition, three attributes must be present in the future workforce: (a) a capability at skills, tasks, and jobs that go beyond the current skills, (b) a mindset that is used to learning and capable of additional learning/training, and (c) flexibility and adaptability. The understanding of and ability to apply these competencies will produce a technologically literate future worker. (Graham & Rosenthal, 1985; Lund & Hansen, 1983; Adler, 1987; Marchello, 1987; and Nemeec, 1987).

The systemic problem solving model for technology transfer highlighted in Figure 5-2 is designed to foster such a learning environment. Details of its use are found in Barnes (1988). This model allows one to enter and exit at different points and to move around freely depending upon prior knowledge and ability to understand the problem. It is built upon integrative continuous learning and problem solving theory implemented through a systems approach. This model, then, provides a framework with which to study technology from a futuristic viewpoint.

Corporation and Education Partnerships

The corporate sector supports long-term education projects to foster education reform and the development of a technologically literate workforce. Corporations have already made this type of commitment.

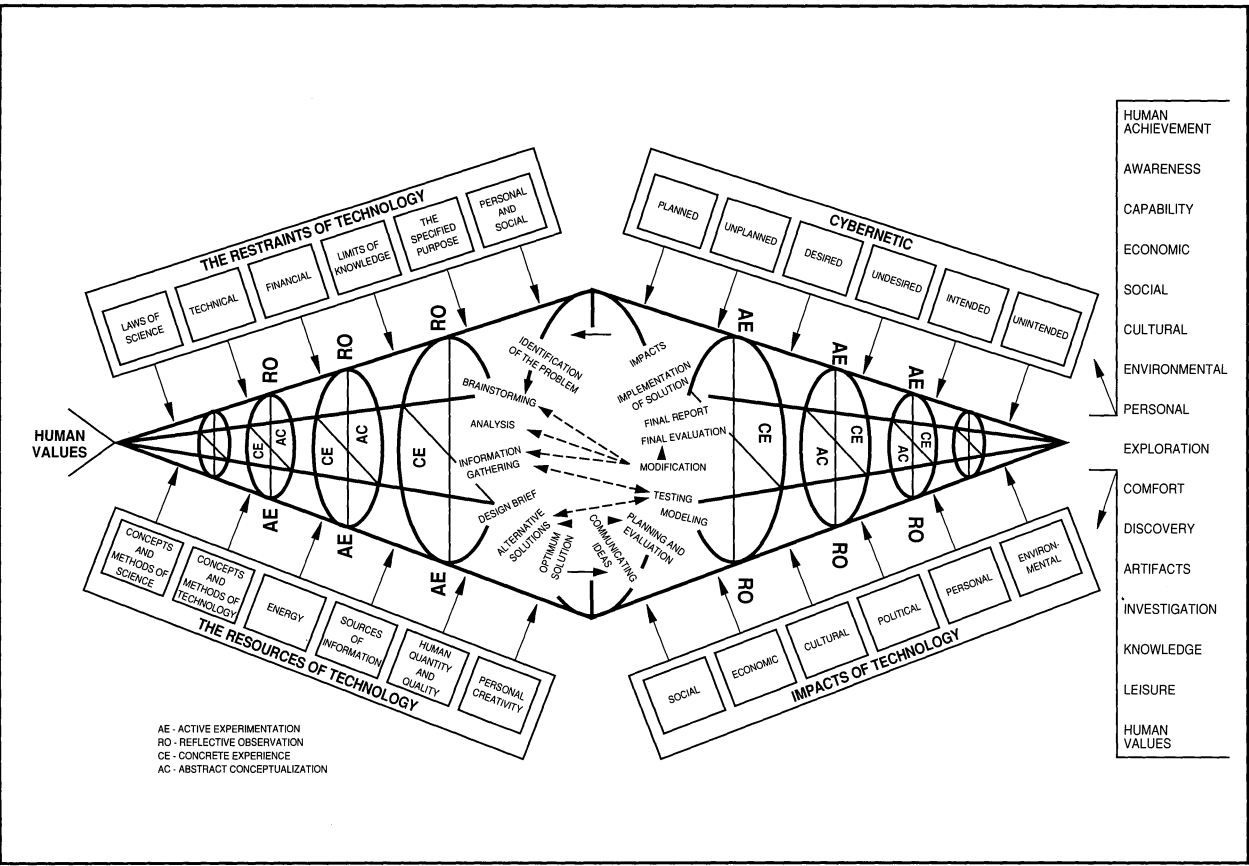


Figure 5-2. Systemic model of problem solving for technology transfer.

These initiatives include:

- Apple Computer Corporation's Apple Classrooms of Tomorrow;
- Dayton-Hudson Corporation's dropout prevention program;
- Amoco Corporation's program to identify emerging jobs and prepare students to compete for them;
- ARCO supports programs for low-income and minority students;
- Georgia Pacific Company's program that allows its employees to teach a variety of courses at all grade levels;
- IBM's "Write to Read" program;
- Digital Equipment Corporation's traveling computerized classroom;
- General Electric and Hewlett-Packard programs to improve math and training;
- NASA's summer teacher and student programs;
- Honeywell's summer teachers academy; and
- Fairchild Aircraft's hi-tech internship program for students.

Although short-term projects are not the best solution for enhancing technological literacy through corporate partnerships, they do play a role in the process. Among the other approaches are: (a) advisory committees, (b) consultants bureaus, (c) sponsored research, and (d) contest judges and evaluators.

Advisory Committees

Having corporate leaders serve as members of technology education advisory committees will bring expertise, credibility and respect to programs. These individuals can advise the technology educator and influence the administration and education governing bodies on matters that require technical expertise. This advice could include updating of the curriculum and facilities, identifying funding sources, and providing student scholarships. These advisors can also be resources to help solve problems related to any technological activity.

Consultants Bureau

The corporate consultants bureau provides a wellspring of dedicated corporate leaders who are willing to help technology educators and students solve technological problems. In concept, a corporate leader is willing to consult with a student in the consultant's area of expertise. The consultant can help by providing students with research materials, answering questions on technical matters, or referring students to other experts in the field or other resources.

The bureau can aid the technology educator by providing speakers on specific technology topics. It can also be a source for technical assistance to help the educator design and construct apparatus and instrumentation necessary to teach technology.

Corporate Sponsored Research

The concept of corporate sponsored research provides enormous benefits to the student, teacher, and corporation. A sponsoring corporation would provide the funds for a student to conduct research in concert with that corporation. The student would not only work at school on the research project, but would also work with an assigned unit of that corporation. The student research would be published or presented through appropriate means.

Technology teachers could work as interns during the summer to upgrade their knowledge in technological areas. Teachers work side-by-side with expert engineers, technicians, and technologists, and then take the knowledge gained from these experiences back to the classroom and laboratory to build stronger programs.

Contest Judges and Evaluators

In TESA and TECA activities, corporate leaders can serve as contest judges. However, this should not include judging "bigger and better" craft projects. Instead it should involve judging problem solving and critical/creative thinking contests or technological problems.

Corporate leaders can also help evaluate student work. In this case the leader would serve on a panel to hear students defend their work on technological problems. Through this mechanism, students, teachers, and corporate leaders can exchange solutions to technological problems in order to reach viable solutions to problems.

Labor Involvement

Increasing the understanding of technology among our working population will require several approaches. For the long term, improvement of our public education system is required, and both the AFL-CIO and its main education affiliate, the American Federation of Teachers, are actively engaged in the reform effort getting underway.

Dealing with more immediate problems requires the utilization of every available means of adult education. One route that serves the working population specifically is the development of courses of study by the unions themselves. For example, the Machinists Union runs

a major education center at Placid Harbor, Maryland. Among the courses offered to staff and local leaders is a series dealing with technology at the workplace. These courses begin with attempts to develop an awareness of what is happening in the workplace, what new technologies are being introduced and where, a discussion of national issues and the response of the IAM, and finally, a discussion of possible local union responses and how to design an effective program.

One of the most detailed statements of how unions think about technology is outlined in the workers technology bill of rights (IAM, n.d.). Some of its key provisions are highlighted in Figure 5-3.

Several other unions are developing their own programs and other courses are presented at the George Meany Center for Labor Studies in Silver Spring, Maryland. This facility, operated by the AFL-CIO, is available to affiliated union staff and leadership from around the country. In addition, the AFL-CIO's Department for Professional Employees over the past few years has produced several major conferences and publications on technological change.

All of these activities and more will eventually produce large numbers of technologically literate union leaders and staff at all levels. Even more is required to provide the general membership with the information and understanding they need to participate fully in our modern world.

In a society where large numbers of people, including a former President of the United States, believe there is something more than fantasy to astrology, the need to raise the general level of technological literacy is immense. American labor unions have recognized the need. They have been working on these issues for some time. Much more needs to be done, and it needs to involve every level of the American education system, governments, and employers.

- I. New technology shall be used in a way that creates jobs and promotes community-wide and national full employment.
- II. Unit labor cost savings and labor productivity gains resulting from the use of new technology shall be shared with workers at the local enterprise level and shall not be permitted to accrue excessively or exclusively for the gain of capital, management and shareholders. Reduced work hours and increased leisure time made possible by new technology shall result in no loss of real income or decline in living standards for workers affected at the local enterprise level.
- III. Local communities, the states and the nation have a right to require employers to pay a replacement tax, on all machinery, equipment, robots and production systems that displace workers, cause unemployment and, thereby, decrease local, state and federal revenues.
- IV. New technology shall improve conditions of work and shall enhance and expand the opportunities for knowledge, skills and compensation of workers. Displaced workers shall be entitled to training, retraining and subsequent job placement or re-employment.
- V. New technology shall be used to develop and strengthen the U.S. industrial base, consistent with the Full Employment goal and national security requirements, before it is licensed or otherwise exported abroad.
- VI. New technology shall be evaluated in terms of worker safety and health and shall not be destructive of the workplace environment, nor shall it be used at the expense of the community's natural environment.
- VII. Workers, through their trade unions and bargaining units, shall have an absolute right to participate in all phases of management deliberations and decisions that lead or could lead to the introduction of new technology or the changing of the workplace system design, work processes and procedures for doing work, including the shutdown or transfer of work, capital, plant and equipment.
- VIII. Workers shall have the right to monitor control room centers and control stations and the new technology shall not be used to monitor, measure or otherwise control the work practices and work standards of individual workers, at the point of work.
- IX. Storage of an individual worker's personal data and information file by the employer shall be tightly controlled and the collection and/or release and dissemination of information with respect to race, religious or political activities and beliefs, records of physical and mental health disorders and treatments, records of arrests and felony charges or convictions, information concerning sexual preferences and conduct, information concerning internal and private family matters, and information regarding an individual's financial condition or credit worthiness shall not be permitted, except in rare circumstances related to health, and then only after consultation with a family or union-appointed physician, psychiatrist or member of the clergy. The right of an individual worker to inspect his or her personal data file shall at all times be absolute and open.
- X. When new technology is employed in the production of military goods and services, workers, through their trade union and bargaining agent, shall have the right to bargain with management over the establishment of Alternative Production Committees, which shall design ways to adopt that technology to socially-useful production and products in the civilian sector of the economy.

Figure 5-3. Workers' Technology Bill of Rights (International Association of Machinists).

SUMMARY

The demands of the future strongly support the necessity for developing a technologically literate workforce to enable the United States industries to compete in a global market. The evidence overwhelmingly implies the need to develop multi-pronged, multi-level training and retraining programs that engage all citizens, students and the existing workforce in initial and lifelong learning. The certainties and uncertainties of the future, coupled with the advancement of knowledge and technology, simply underscore the importance of developing a multi-skilled workforce which is flexible and adaptable to change.

The research also supports the notion for broadening the concept of **skill** to include more kinds of responsibility, more procedural expertise, and social skills necessary for teamwork. This must include the ability of workers to think critically and creatively and to utilize problem-solving skills in order to solve manufacturing problems. The research findings also indicate the need to understand systems and their subsystems. The future workforce must be able to communicate and to access information in a variety of ways.

The technological literacy perspectives of government and the military are somewhat varied and not as clear cut as many educators might anticipate. There remain many issues that must be dealt with in terms of national security, international competitiveness, and the development of Third World nations. It is hoped that by transporting technology to developing nations, the United States builds friends who will assist us in world ventures and who will contribute to our overall security.

As Third World nations begin developing technology and applying it, these nations can develop their economies (Rosenberg & Frischtak, 1985). In such cases, it may be important for the U.S. to export some technology to assist these nations. By assisting developing nations in raising their standard of living, it increases the potential demand for products and services produced by U.S. firms. This translates into profits and jobs for Americans.

With respect to the education of the citizens of this nation, the government has concerns about a high level of literacy in all areas to ensure the maintenance of our democratic form of government. One of the results has been the incorporation of the Technology Education Demonstration Program into the Omnibus Trade and Competitiveness Act of 1988 by the U.S. Congress to help states develop effective pro-

grams of technology education and technological literacy. As our society becomes more and more technologically based, it will be imperative that the citizens be educated about technology, its history, its promises, its possibilities, and its impacts. Invariably, governments at all levels will become more interested in technology education and in fostering its deployment.

Translating the private sector's messages into learning environments for developing technological literacy supports the notion for holistic and lifelong learning. To prepare one to solve tomorrow's problems, it is crucial to create a learning environment that fosters the development of problem-solving, and creative and critical thinking skills and abilities. The learning environment should also provide experiences to develop good communication skills and group work skills. The environment must be flexible and provide experience with known and unknown technologies.

In order to develop technological literacy successfully, it will be imperative to involve the corporate world through partnerships of various kinds. However, these partnerships must not be short-term or charity-based. They must be long-term and tied to corporate policy. Steve Nielsen of (then) Pacific Northwest Bell stated that business generally gets involved in cursory, fun, easy, and cheap educational activities—these are clearly not sufficient.

There are three generic inputs or influencing factors that affect the development of technological literacy and the transfer of technology or knowledge: (a) human values, (b) restraints on technology, and (c) resources of technology. The restraints on technology are those factors that limit or hinder optimum solutions to technological problems. The resources of technology are those factors which provide positive help toward the optimum solution to a technological problem. Human values provide the balance or common denominator between the restraints on technology and the resources of technology. Over time, human values maximize the resources that extend the knowledge base, thus producing more technologically literate citizens.

It is imperative that the study of technology be organized in a curriculum model of manageable components that are universal to a holistic study of technology. It must also be organized in such a manner as to allow for the transfer of knowledge from one technology or problem to another. By doing this, one can logically analyze and organize any study by utilizing these universal constants of technology as major headings of the technology or problem to be studied.

The curriculum model highlighted in Figure 5-4 suggests a process approach to the study of technology. Problem solving is the technological method and the component that drives the curriculum. The curriculum is organized under three major categories: (a) systems of technology, (b) research and development, and (c) design and innovation. The content to be taught is analyzed and organized under three headings: (a) elements of technology, (b) limits of technology, and (c) impacts of technology.

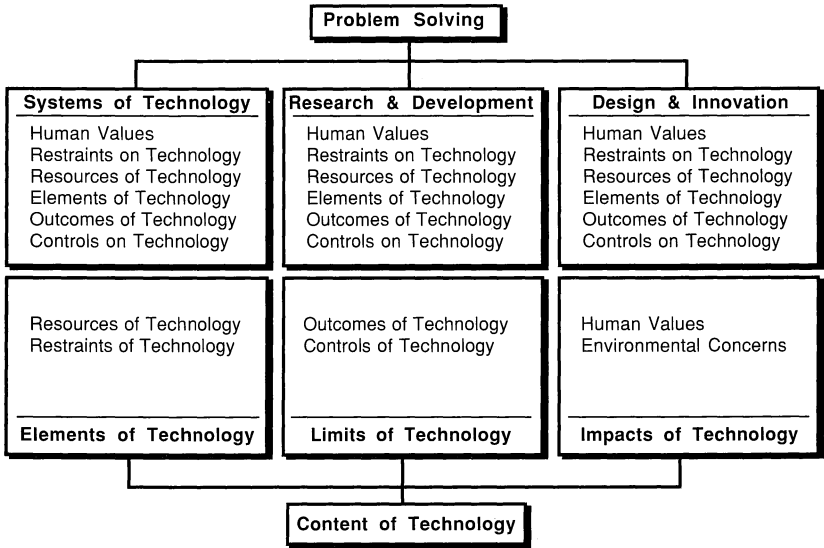


Figure 5-4. Framework of technology.

Under these universal constants any technology can be studied. This organizational structure provides a system for transferring knowledge from one study to another. Thus this method provides the basis for one's thinking in technology so tomorrow's problems can be solved (Barnes, 1988).

CHAPTER SIX

EDUCATIONAL PERSPECTIVES ON TECHNOLOGICAL LITERACY

by
M. James Bensen¹

Views of what education is all about are as diverse as the number of people who are asked. Everyone seems to be an "expert" when it comes to education, yet even those who are the leaders and practitioners in the profession have difficulty in coming to consensus. Few would disagree that individuals within our society, and society as a whole, should be served by education. In addition, most would agree that we are living in a highly advanced and rapidly expanding technological society that is global in nature. Yet why is it that few people throughout the world come to the simple conclusion that the study of technology ought to be central to the education of everyone? After all, everyone is interacting and working daily with, purchasing, consuming, and being impacted by technology, yet very few have even a basic understanding of the principles and processes of this phenomena!

Originating with *Symposium 80: Technology Education*, held at Eastern Illinois University, the symposium series has played a major role in sharpening the theory and outlining the practice of education program development in the study of technology. These symposia, which are held annually, have grown in prominence to the point where they attract educators from all levels and from throughout the country. Two of the symposia have used "technological literacy" as the theme of the program.

TECHNOLOGICAL LITERACY

The term **technology** appeared in both the popular press and in the professional literature for a number of decades before many took upon

¹M. James Bensen is President, Dunwoodie Industrial Institute, Minneapolis, Minnesota.

themselves the task of defining it. Even though the term "technology" appeared in the dictionary, many educators who were working in the field felt it to be a narrow and somewhat limiting definition for a major dimension of the human experience. This perspective has changed, and currently more expanded and comprehensive definitions of technology appear in documents of the profession. Technological literacy appears to be following the same pattern in arriving at a definition that is accepted by the profession. In fact, part of the intent of this yearbook is to generate discussion and build support for a clear statement on technological literacy.

Until further refinement of the term is achieved in the field, technological literacy will be discussed as defined by Loepp as "the competency to locate, sort, analyze, and synthesize information that relates to achieving practical purposes through efficient action" (Loepp, 1986, p. 37). To be consistent with the praxiological nature of technology, technological literacy necessarily includes, in addition to Loepp's features, the ability to do.²

Educating the Work Force

Technological literacy is often developed, supported, and promoted as an integral part of general education. However, it can also be used as a career orientation tool and can take on a straightforwardly utilitarian role. The Advanced Center for Technology Training, Inc., (ACTT) headquartered in Farmington Hills, Michigan, is a for-profit corporation that provides advanced training programs for "hi-tech" industry. They offer specialized courses in such areas as computer integrated manufacturing, robotics, vision systems, and programmable controllers. With much of their work based on the principles of the international Organization for Rehabilitation through Training (ORT), ACTT also specializes in technology literacy training. They (1987) point out that:

Experience with today's American work force has led to a general recognition that effective technological training has three components: Basic skills training (reading comprehension and math skills), equipment and machine-specific training, and training to bridge the gap between them. The latter, intermediary training, is technology literacy (front-end training) and is depicted in Figure 6-1.

²Eds. Note.

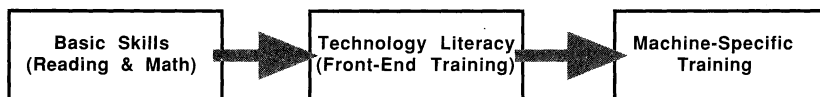


Figure 6-1. Technological literacy according to ACTT.

The Advanced Center for Technology Training, Inc., defines technology literacy training as:

Training that spans the gap between basic skills training and machine-specific training...technology literacy training is based on a model that leads workers to learn the vocabulary and syntax of technology, develop strategies to solve problems, analyze data and work with equipment in these processes (ACTT, 1987, p. 5).

The Social Conscience

William Raspberry (1988), writing in the *Washington Post*, notes that we as an American society see ourselves as elevating symbols above substance. We teach all children as though we expect them to go to college and train for the professions. While Raspberry was citing the manual skills as going undeveloped in this society, he calls for a balance in our educational programs of both the traditional academic and the technological. He also indicates that the dignity in work of all types must be stressed, as he refers to past experiences when "we grew things, made things, repaired things, sold things, and we were justly proud of our skills." He also states that "we are leaving more and more to others—notably the Japanese—to manufacture the things we use, contenting ourselves with the ephemeral of financial manipulation." Drawing on the observations of Raspberry, the question arises, "Are we on a downward spiral of inaction by moving the emphasis of education away from that which is technological?" Or, "Are we in a sense 'mortgaging the future of our country'?" as an industrialist stated to this author one day when discussing technology.

PERSPECTIVES OF KEY EDUCATIONAL ORGANIZATIONS

Significant among the more global indicators of overall progress in education are the positions adopted by its key associations. These groups serve as levelers of opinion and thereby prevent too radical a

change from being foisted upon the public. They do so by providing opportunities for positions to be heard, examined, and modified so that intended and unintended outcomes align with the overall objectives. They also provide a most important forum for the interface between single focus and more pluralistic organizations. Above all, when taken together, their critical mass is essential to advancement of the practice of education. For these reasons and more, this author examined the positions of leading educational associations and purposefully emphasized those outside the technology education profession's core.

Phi Delta Kappa

The attempt of educational organizations, from throughout the larger profession, to provide focus, direction, and leadership in developing technological literacy is limited at best and non-existent in many cases. For instance, in communicating with Phi Delta Kappa, it was learned that they had no formal definition of technology and had not developed a definition and/or perspective on either "technological literacy" or technology education. Even in a statement on the future, developed by the PDK Futures Committee, entitled, *Phi Delta Kappa: 2000 and Beyond*, technology as a force in our changing society or as an impact on education was not addressed directly (Frymier, et al., 1986). PDK does, however, occasionally feature articles in the *Kappan* that provide an educational perspective on issues related to technological literacy. One such article which caught the eye of the profession was a feature by Jennings, on "The Sputnik of the Eighties." Jennings, Counsel for the United States House Committee on Education and Labor, proposed spurring the U.S. Congress to support legislation for new education programs in "mathematics, science, and foreign language instruction, as well as programs to improve literacy and to promote technological innovations" (1987). The emphasis in the article was to demonstrate the growing recognition of the tie between educational and economic competitiveness.

Phi Delta Kappa, as a professional fraternity in education, has differing goals and mission than do organizations that focus more on the economic welfare and working conditions of professional educators. Hence, they have a powerful voice in speaking across the normal disciplines of education without being put in a frame of reference of a special interest group. Thus, support from an organization such as this for technological literacy would be significant.

American Federation of Teachers

Communication with AFT President Albert Shanker, indicated that the American Federation of Teachers has "ideas and materials on the issue of technology in education" but does not have information on "technological literacy or technology education." President Shanker, however, related that he has a personal interest in technology and that he was on the advisory board of Project 2061 of the American Academy for the Advancement of Science, which "devotes major attention to technology education" (Shanker, January 12, 1989).

National Education Association

In correspondence with NEA it was indicated that they had a keen interest in technology and had developed an official stance on it. A number of documents and papers were sent to provide clarification and substantiate the interest of the NEA in their inclusion of technology as an important element in education. In examining the materials that they included in their correspondence, however, it was evident that they were making reference to **instructional** technology and not technology education or technological literacy (NEA, 1988). This is a common misunderstanding in the educational profession and one that has to be addressed in the future.

The American Association for the Advancement of Science

The AAAS has underway a major study called *Project 2061: Education for a Changing Future*. This project, "is founded on the conviction that everyone—not just those bound for college and science careers, but everyone—should gain, through elementary and secondary education, an essential understanding of science, mathematics and technology" (AAAS, 1989). One significant part of this study's report addresses technology and technological literacy and makes recommendations for the inclusion of this dimension of the human experience in the education of youth. Chapter 8, entitled "The Designed World," identifies eight "basic technology areas: agriculture, materials, manufacturing, energy sources, energy use, communication, information processing, and health technology" (Rutherford, 1987). In Section 2, of the most important *Project 2061 Panel Report on Technology*, Johnson outlines a framework for technology. He writes:

The people who generate new technology or control its use often do so by first considering a framework of intercon-

nected questions designed to lead to a full understanding of the likely effects and implications of the technology. These questions—as presented below—should also be familiar to the technologically literate citizen:

- What is the goal? What is to be done, to be made?
- What can be conceived or invented to achieve the goal? Born of need, how does technology evolve through ideas, designs, or plans to practice?
- What knowledge and know-how are needed?
- What materials will be used to construct the artifacts of the technology?
- What tools or machines can be used to help do it or to make it?
- What energy source will drive it, form it?
- Does it function alone or should it be incorporated into a system or network?
- How is its manufacture or use to be operated, controlled, and managed for optimum efficiency and quality?
- Does the technology serve the original goal or purpose?
- Does it compete in the local and global economic systems?
- What are the mechanisms by which the technology enters social systems?
- Is it safe according to accepted risk/benefit standards?
- Does the technology put at risk the users, or other people who are not beneficiaries?
- What are the technology's effects on the environment and human well being?
- As it becomes obsolete or worn out, how is its manufacture or use terminated? What is done to safely dispose of its used materials?
- Will the technology have long-range effects on the course of human history?

The technologically literate citizen would not only understand the questions but also be familiar with the ways in which answers are developed (Johnson, 1989, p. 4).

Project 2061 is a major long-term effort to restructure education to better meet the needs of the future. At the current time it is entering its second phase of development in which pilot schools are developing programs to implement the recommendations of the project.

The Humanities and Technology Association

The HTA, linked with Southern College of Technology in Marietta, Georgia, is primarily a higher education group. In personal correspondence, Morrow (1988) relates that the organization sponsors an annual conference on Humanities and Technology, but "does not have either a perspective or definition of technology, technological literacy, or technology education." An examination of Interface '87, their conference program, reveals that a strong mix of the presenters of papers come from a variety of disciplines (*Interface '87*, 1987).

National Association for Science, Technology and Society

The NASTS also provides focus to the importance of technology as a central phenomena in the development and well being of society. Unlike many organizations which use technology interchangeably with science, NASTS identifies technology for what it is and places it on an equal plane with "science and society." NASTS also understands that technology does not mean "computers" as many administrative practitioners seem to assume in our school systems. NASTS, until recently, was a rather loosely organized group of interested people who had a common interest. The early "STS group" officially organized into a national association and now holds the promise of becoming a more powerful entity in the promotion, development, and support of the study of technology in educational programs. For over five years the group sponsors an annual national technological literacy conference to bring together educators from the K-12 and university levels. Recently, increased emphasis has been placed on including the private sector. The conferences have provided an excellent forum to exchange ideas and promote technological literacy and the integration of Science, Technology and Society ("STS") programs into the mainstream of education.

Technological literacy is a prime focus of this organization. Note, for example, that in the STS brochure, announcing the 1986 conference on Technological Literacy, the following definition is given: "Technological literacy—essential for effective citizenship. Technology literacy means **understanding** the technological and scientific forces shaping our lives, and in being able to **act** on this understanding for our **personal welfare** and **common good**" (STS, 1986).

The Council for the Understanding of Technology in Human Affairs

The CUTHA, has interests along the lines of STS, but seems basically to have its roots in linking the engineering profession to the humanities. Courses and interactions that cross over in the areas of higher education are encouraged. CUTHA also bills itself as "an educational organization dedicated to the advancement of technological literacy." *The Weaver*, the official publication of CUTHA, uses the byline in its title, ". . .of Information and Perspectives on Technological Literacy," to connote the intent of weaving together into some whole, the concepts that make up our technological world (CUTHA, 1986, p. 1). Editor Edith Ruina writes, "Almost without exception, each writer considers technological literacy planning development as means for encouraging cooperation among varied disciplines, a most welcome 'fall out effect'" (1986, p. 1).

In a statement of purpose, The Council for the Understanding of Technology in Human Affairs:

promotes the development of technological literacy by sponsoring workshops, seminars, and publications for educators and by consultation. The Council fosters collaboration among engineering and liberal arts educators and enlists the participation of representatives of industry, government, professional organizations, and public interest groups concerned about the role of technology in human affairs" (*The Weaver*, Spring 1986).

It should be noted that the membership and interests of STS and CUTHA are overlapping and often led by the same people and institutions. For instance, in an article in the *Bulletin of Science, Technology, and Society*, in 1982, Goldman and Cutcliffe point out the difficulties that cross disciplinary studies such as STS have experienced in university settings. They relate that over a period of fifteen years "...STS had to earn academic respectability in the face of persistent, and often vigorous, criticism that interdisciplinary studies guaranteed superficial scholarship, that innovative teaching approaches sought to substitute classroom popularity for publication and research achievements, that the focus on social issues was a platform for destructive anti-establishment carping" (Goldman & Cutcliffe, 1982). They went on to give a snapshot view of the beginning of the STS program efforts through CUTHA with the following statement:

The opening salvo in this newest "literacy" campaign would appear to have come from a group of prominent engineering educators, led by Dean Edward Friedman of Stevens Institute of Technology, who three years ago formed the Council for the Understanding of Technology in Human Affairs (CUTHA). CUTHA's announced purpose was to promote the study of technology by college students not majoring in science or engineering ... CUTHA has matured as an organization in the course of the past three years. With the support of AT&T, Exxon, and U.S. Steel, it now has an office and staff at MIT...In spite of this maturation, however, it seems likely that the recent intense media coverage given to technology literacy is attributable not to CUTHA's steady efforts in academic circles, but to recent heavy public and political promotion of this cause by the Sloan Foundation, the Carnegie Institute for Higher Education, the National Science Foundation, the National Research Council, the National Academy of Science, the American Association for the Advancement of Science, and most recently the Association of American Colleges, representing the special interest in curriculum development of its seven hundred arts college members (Goldman & Cutcliffe, 1982, p. 292).

The International Technology Education Association

The ITEA has as its primary mission, to: "(1) define, stimulate, and coordinate the ideal form of technology education as a vital aspect of education for all students on all levels and (2) to promote the improvement of the quality of instruction in technology by assisting educators, students and all others concerned to keep instructional content, methods, and facilities current with the rapid changes in industry and technology" (ITEA Professional Improvement Plan, 1988). The organization defines technology education as "a comprehensive, action-based educational program concerned with technical means, their evolution, utilization and significance; with industry, its organization, personnel, systems, techniques, resources and products and their social and cultural impact" (*Technology education, The new basic*, n.d.).

Though the International Technology Education Association has used the term "technological literacy" frequently for over a decade, this concept is less well defined in their literature. For example, ITEA,

as many organizations, has developed a philosophical statement entitled *This We Believe: Technology Education* (ITEA, n.d.). An analysis of this statement does not reveal the actual use of the term "technological literacy." Yet many would support the position that the emphasis of the "this we believe statement," when taken as a whole, does identify the important components of an education program that promotes and develops technological literacy. Key terms in the document that point to this focus are:

- ...understand, function, and control their industrial/technological environment.
- ...awareness of industry and enterprise and their place in the world culture.
- ...opportunities to discover their talents and abilities in the areas of technology...
- ...developing insights into technology, its evolution, utilization and significance...
- ...Provides technical skills and knowledge basic to most occupations and professions...
- ...solve technical problems,...develop knowledge, skills, and the ability to obtain technical information...
- ...develop interest in the human-made world—its materials, products, and processes.
- ...involve self-evaluation of attitudes towards constructive work and how this work can be utilized...
- ...development of a favorable attitude toward creative thinking, and toward character improvement...
- ...knowing and making the most of one's environment.
- ...involvement of tools, machines and materials, which reinforces the written and spoken word.
- ...derive meaning from concrete experiences which aid in the understanding of abstract ideas and the development of concepts.

Collectively, the above statements, as abstracted, form a powerful supporting documentation of ITEA's support of technological literacy in program design.

One of the often featured publications of the International Technology Education Association, entitled, *Technology Education: A Perspective on Implementation* (1985), provides emphasis to the need for establishing a measure of technological literacy. In it, Johnson, writing on "The Nature of Our Technological Society" states:

...we must not only understand technology, we also must energize it, use it, cope with it. As the gifts of technology become more pervasive and its concomitant problems more critical, there is a more compelling need for broader understanding. The technologist must give more thought to the uses of technology and their impact on society. The non-technologists must no longer regard technology as something that works magic for or against them.

Much has been said of "technological literacy," meaning that the non-technologists must learn some technics. But this is not enough. Modern technology and its societal meanings, require a holistic, integrated understanding that permeates all segments of our society. This is for education a goal whose time has come (p. 11).

At the time that this chapter was being written, ITEA had drafted its 1990-95 Professional Improvement Plan. Though not yet published, the draft document has as its main mission "to advance technological literacy." It goes on to identify six goals to carry out this mission:

- I. Provide a philosophical foundation for the study of technology that emphasizes technological literacy;
- II. Provide teaching and learning systems for developing technological literacy;
- III. Foster research to advance technological literacy;
- IV. Serve as the catalyst in establishing technology education as the primary discipline for the advancement of technological literacy;
- V. Increase the number and quality of people teaching technology; and
- VI. Provide for a consortium to advance technological literacy (ITEA, 1989).

The Technology Education Division of the American Vocational Association

The TED/AVA is consistent with the International Technology Education Association in the promotion and support of technological literacy as one of its primary program goals. The division's new strategic plan documents the organization's mission as being the promotion of technological literacy (TED, 1989). This is a thrust that traces back to 1953, when, in *A Guide to Improving Instruction in Industrial Arts*, the American Vocational Association, proposed industrial arts as general

education. The document states that "the purpose of general education in the United States is to develop common values, skills, understandings and appreciations based upon the fundamental tenets of democracy. Since these values, skills, appreciations and understandings serve a social-integrative purpose, they center about the common core of enterprises which all the people share" (IAD, 1953, p. 10). Thirty-five years later the terminology has changed somewhat, because of the rapidly changing and tremendously complex technological context, yet the intent of the programs remains relevant and focused on the broad orientation of the technological world.

In a carefully drafted position paper by Dyrenfurth, an officer of the TED, it is proposed that the early forms of collective arguments for technological literacy stemmed from the industrial arts profession. He relates, however, that the task is large and that it will take a comprehensive thrust toward technological literacy involving schools, other educational institutions, and the cooperation of radio and television networks, museums, libraries, and other public resources as well as collaborative efforts with the private sector (Dyrenfurth, 1984).

Individual State and Council Positions

The initiation of the change from the traditional industrial arts programs to those that include the study of technology has a number of roots. Among the more significant of these was the perspective developed by Warner in 1939 (Warner, et al., 1965). Several research and curriculum projects followed in the decade of the 1960's, but it was not until the Industrial Arts Program at West Virginia University officially changed its name to the Technology Education Program in 1973 that any formal change took place.

The move by professional associations to reflect identification with technology education began with the Wisconsin Industrial Education Association changing its name to the Wisconsin Technology Education Association in 1982. The American Industrial Arts Association made the change the following year to the International Technology Education Association. Since that time over forty state associations and all of the ITEA affiliate councils and student organizations have made formal changes to include "technology" in their names. Additionally, one regional professional organization, the Southeast Technology Education Association, has also followed with a change. Such actions represent more than individual organizations changing their own iden-

tity. They reflect a shift in perceptions of others in education. For example, it is significant to note that in 1989, in order to change its name to the Technology Education Division, the Industrial Arts Division of the AVA successfully secured a delegate assembly vote of the **entire** AVA constituency. This concurrence by other key groups that share the stage with technology education demonstrates progress in the concept's "coming of age."

PERSPECTIVES RELATED TO SCHOOLING

K-12 Perspectives

An example of the emphasis being placed on technological literacy at the state level is found in the state guide published by the Wisconsin Department of Public Instruction. It reads:

Technological literacy stems from a comprehensive education process designed to develop a population that is knowledgeable about technology, its evolution, systems, techniques, utilization in industry and other fields, and social and cultural significance. The technologically-literate student has been exposed to a set of concepts, processes, and systems that is uniquely technological, and has fundamental knowledge about the development of technology and its effects on people, the environment, and culture. Technologically literate students will contribute significantly to making our world a better place in which to live (Wisconsin Department of Public Instruction, 1988, p. 29).

The New York Technology Education Curriculum also calls special attention to the need for technological literacy. In their guide for the junior high school program they state:

Many of the issues confronting people involve technological interactions. This integration of technology into society creates complexity and demands that we become technologically literate. Our quality of life can be preserved and improved if we recognize and study how our ecological and technological systems interact. Fundamental education in our society should impart an understanding of the possibilities and limitations of technology in order to assist future citizens to make intelligent decisions and to instill in them a

sense of environmental and social responsibility. The control of technology requires knowledge, awareness, decision making, and leadership" (The New York State Education Department, p. 1).

As a part of the publications package that the State of New York has developed to promote and encourage participation of the private sector, a *Technology education: Public information handbook* has been made available for schools. In it, a sample letter to a local business or chamber of commerce states that "Technology Education is an exciting new discipline that motivates students and develops technologically literate citizenry." With that statement as a backdrop, the letter goes on to ask for the support of the local business in bringing about this necessary component in society through the education of the youth of the community (New York State Education Department, 1987).

Teacher Education

Much of the success in implementing education programs to foster technological literacy will depend upon leadership in teacher education. This leadership is required for both preservice and inservice modes. To give an indication of the strength of the technology education movement, it should be noted that a significant number of preservice programs in technology education have been developed across the United States and the profession now has come to the point where the University of Illinois has proposed an "Illinois Center for Technological Literacy" to provide a base for its teacher education programs (Erekson, 1986, p. 12).

A growing number of technology teacher education programs are currently in operation to produce "teachers of technology." Under the joint leadership of the Council of Technology Teacher Education and the International Technology Education Association, Standards for Technology Teacher Education have been developed. These standards have been approved by the National Council for Accreditation in Teacher Education (NCATE) for use in the evaluation of programs.

Since formal name change processes in colleges and universities sometimes move slowly, many preservice teacher education programs have actually restructured their curriculum around a contemporary technology base although this is not reflected in the official name of their program. However, a review of the 1988-89 *Industrial Teacher Education Directory* does reveal that over two dozen colleges and universities have made a change in their program titles to reflect this new emphasis (Dennis, 1988), and more are imminent.

The Engineering Education Perspective

The University of Wisconsin System undertook an eighteen-month study of the future of, and requirements for, engineering and technology programs across the state. The task force appointed to undertake the study was from both industry and higher education. In the introduction of the report entitled *Better Living Through Technology: Wisconsin at Risk, 1989*, it is stated:

To meet the challenges that are likely to impact engineering and technology education in the University of Wisconsin System during the next decade, it is imperative to consider technical education at all levels, from elementary school through graduate programs and on to the lifelong learning needed to keep faculty and graduate engineers and technologists current. The demand for education and for new knowledge is inseparable from the technological innovation that pervades our society and is transforming the workplace. Wisconsin needs engineers and technologists, but it also must have available a pool of technologically literate managers and workers prepared to accept the challenge of competing in the global marketplace (UW-System, 1989, p. 5).

The report more specifically points out that "recognizing that technology is different from math and science, it is imperative that the study of technology be required to provide an application of the other disciplines and to place our citizens in control of their future." The task force supported this statement by placing one of its major recommendations as follows:

Broadening Technological Literacy:

The most striking feature of our culture is its rapidly advancing technology. The least common feature of our educational system is awareness of technology. Technology education is needed at every level, kindergarten through college. Materials are available. Now is the time to make an impact.

Objective 4: To improve technological literacy of all citizens of Wisconsin and increase the number of Wisconsin high school graduates interested in and qualified to pursue careers in engineering and technology.

Recommendation 4.1: Establishing a Technologically Literate Citizenry.

The well-being of our society and the competitiveness of our state and nation depend upon well educated citizens. With the exploding technological knowledge base, both precollege schools and the University of Wisconsin System must provide an education that includes a strong focus on technological literacy.

- A. For K-12 students: The UW-System should encourage the Department of Public Instruction to require a unit in Technology Education for high school graduation.
- B. For UW students: The UW-System must encourage inclusion of the study of technology as an integral part of general education requirements in the UW System.
- C. For new teachers: The UW-System must cooperate with business and industry to help K-12 teachers include technology education.
- D. For experienced teachers: The UW-System must cooperate with business and industry in K-12 teacher enrichment programs to increase technological competence and understanding of the impacts of technology (UW-System, 1989, pp. 18-19).

It is striking to note from the recommendations of the study that the recognition of technological literacy must become central to the curriculum of all learners, be understood by our teachers, and is one of the prime elements to determine the virtual survival of our society.

Community-Based Education

An alternative educational approach to technological literacy is being developed in the Minneapolis-St. Paul area. The program, entitled, "City Works," is organizing a hands-on "technology discovery center" and is based on the experiential concept of San Francisco's Exploratorium. It has as its purpose to "...increase public awareness and understanding of technology and of issues concerning technology and society." City Works projects include:

- establishing a technology discovery center for informal learning about technology: how it works, how it is made, what it does;
- bringing the benefits of that center to the broadest possible audience, lowering the traditional barriers of gender, age, and background in technology;

- exploring methods to enhance learning about technology, with emphasis on participatory, experiential, informal, and learner centered approaches; and
- providing a forum for discussion of human issues in technology and its use: how technology is created, adapted, changed; assess the use of current and future technologies (City Works, n.d.).

City Works, a "museum approach" to providing education to a community, sees the importance of the understanding of technology by all citizens and feels that this can be achieved effectively in an observational and experiential learning environment.

Educational Responses on the International Scene

International efforts to develop technology education programs are becoming more frequent each year. The Craft, Design and Technology programs that operate on the secondary level in the United Kingdom appear to be in the lead among international developments in actual systematic implementation of technology education. A recent conference was held which "celebrated a decade of CDT progress" (Design and Technology Education, 1987). These programs are based on a universal model of technology, developed as far back as 1970, which provides outstanding guidelines for incorporating the process of technology within the restraints and resources of technology.

A major conference on Technology Teacher Education in Australia, held in Canberra in 1986, addressed significant issues in providing direction for the leadership of the profession (Taylor & Middleton, 1986). Likewise, the Pupil's Attitude Toward Technology (PATT) Conference, holds promise as one of the premier international leadership ventures of the profession. This relatively new, and originally annually (now biennial) scheduled conference, presents findings and perspectives related to technology education of researchers from more than twenty countries including a significant number from the Eastern block. They call the problem of technology education a "new school subject without tradition" and they view it as "common to all countries." Therefore, "it is important that there is international cooperation" (Raat, 1987 p. 13).

THE GOAL: A TECHNOLOGICALLY LITERATE SOCIETY

In life, we are confronted with an array of skills, knowledges, attitudes, and process capabilities that are of a technological nature. Many

find this rapidly changing world a bewildering and alien place to live and work as they recoil from the technical means upon which they must rely. Others find that their capabilities have expanded immensely and that they have empowered themselves by being technologically literate. The latter people are able to handle their daily lives with confidence and purpose as a result of their ability to deal effectively with their surroundings. The Technology Education Advisory Council (TEAC), in their publication, *Technology: A National Imperative*, outlines the specific roles of citizen participation on a personal basis:

- As a user of technology in the home, in recreation, in self-development, travel and daily routine;
- As a purchaser and consumer of technology ranging from automobiles to radios, televisions, computers, lawn mowers, refrigerators, boats, toys, games, household fixtures, smoke alarms, microwave ovens, telephones, and countless others;
- As a decision-maker about technology in the home, community, workplace, educational institutions, places of worship, and in public office;
- As an employee or worker in the home, farm, factory, business, hospital, schools, media center, public agency, and a broad spectrum of private and public institutions; and
- As a planner for the future, whether it be a personal project, a public enterprise, or an industry/business proposal.

The individual's involvement with technology and his or her understanding of technology vary in accordance with the part one plays in society. For example, there are those who will be instrumental in the creation of technology. This may require highly specialized information and technological background in a technical sense, but also a sensitivity to Technology Education that deals with the social and environmental impacts of such developments (TEAC, 1988, p. 14).

Over the past decade a surge of activity has taken place in the development of educational experiences that will provide our elementary school, secondary school, and university students, as well as those in the workforce, the opportunity to gain a measure of technological literacy. Much of the key leadership in this development is coming from those in the technology education profession but they are increasingly joined by colleagues from engineering, arts & sciences, humanities, and the private sector.

We live in this highly sophisticated technological society and it is imperative that we understand it, be a contributing citizen to it, experience a rich and fulfilling life in it, and pursue excellence in our work. The Technology Education Advisory Council again pronounces it so well:

Technology Education is an important curriculum breakthrough.

It is an imperative for meaning and effectiveness in a technological society for the individual and all of humanity.

To neglect the study of Technology Education is to further enhance the present state of technological ignorance. This is a direction citizens in a democracy can not afford to travel (TEAC, 1988, p. 15).

CHAPTER SEVEN

TECHNOLOGICAL LITERACY SYNTHESIZED

by
Michael J. Dyrenfurth¹

Given the plethora of informed and uninformed material written about technology and technological literacy, it is a genuine challenge to assemble anything resembling a cogent synthesis. Despite the formidable nature of this goal, such a synthesis is needed to achieve the purposes of this yearbook. Undoubtedly this work will include both Type I and II errors but hopefully it will serve as an adequate point of departure for subsequent adventurers.

This author reviewed, as primary input for this chapter, the contributions of this yearbook's chapter authors. After all, it was they who had been commissioned to represent their constituencies and bring the views, insights and perspectives of these constituencies to our profession. These ideas were melded with the findings of detailed reviews of the literature to generate the synthesis presented in this chapter. In it, first the enlargement of the concept of literacy is documented. This is followed by in-depth examinations of the concepts of technology and technological literacy. Finally, the chapter concludes with the presentation and description of a synthesized model of technological literacy—a model incorporates all of the critical characteristics identified by our profession to date.

MEANING & EVOLUTION OF "LITERACY"

Nature of Literacy

Literacy is not a simple concept. The term has been used in many ways (Miller, 1986). Probably the most popular sense in which the

¹Michael J. Dyrenfurth is Professor of Industrial Education, Department of Practical Arts and Vocational-Technical Education, College of Education, University of Missouri-Columbia.

term is taken is the ability to read and write at a level that allows an individual to function—at least minimally—within our society (Miller, 1986, p. 3). This idea of minimal **functioning**, embodied in Miller's definition, is central to the concept's emerging meaning. Note for example (Benderson, 1983, p. 5). "Literacy . . . means the ability to read and write, that is, to **do** something with a language, not merely to **recognize** that language is composed of words, to **identify** a letter of the alphabet, or to be **aware** of the pervasive role of language in society. [emphases added]" The Educational Testing Service in their 1986 *Annual Report*, summarizes the evolution of literacy well. "Literacy entails a network of skills and is far more complex in the information age than it was in simpler times." They claim that "we don't have an illiteracy problem, but we do have a number of illiteracy problems."

Clearly, others have adopted the wider meaning of the term "literacy." Agricultural, computer and economic literacy have all emerged. Even cultural literacy (Hirsch, 1987) has received widespread attention. Zahler & Zahler (1988), for example, have even developed a book, *Test Your Cultural Literacy*, purportedly enabling the reader to "do it themselves." This book is notable in that the Zahlers have included a section on technology as one of fourteen areas to be tested. However, its sample of questions would not be favorably assessed by our profession's theoreticians since energy & power technology questions dominate with materials & processing and communications technology items taking up only distant second and third positions.

More to the point, however, is that current sources further document the expansion of the term "literacy" from its simplistic meaning, i.e., merely the ability to read and write; to a larger, more encompassing construct. For example, Zahler & Zahler cite Hirsch's (1987, p.2) definition that cultural literacy is "the network of information that all competent readers possess." Moreover they point out the necessity for a common base of shared meaning to facilitate communication—and, as Adler (1982) so cogently argued, for appropriate education and cultural centrism. The latter, of course, Hirsch (1987) argued is not to be found today.

So far, both the expansion of the term's (literacy) meaning to include **functioning** and the solidification of the notion of levels (of literacy) have been described. The next logical step is to document the extension of the term to technological arenas. This direction was recognized as early as 1973 when Daniel Bell pointed out the shift to a post-industrial society. More recently, DeVore (1987) described the extension most cogently. He explored the meaning of technological literacy by

asking "what does it mean to be literate in French or Russian?" He identified the ability to speak, write, and read in the language, "implying a knowledge, understanding and mastery of the words, symbols, syntax and structure of the language as well as the ability to perform using the language." It, technological literacy, also implies a knowledge and understanding of the history and culture of the countries where the language is primary.

The preceding highlights the expansion of the meaning of the concept of literacy. In addition, however, it is also important to recognize that the evolution of the term included increased recognition of the notion that literacy exists in varying levels. For example, Zahler & Zahler (1988) refer to Paulo Freire's observation (in Mackie, 1981) that "to be literate is not to have arrived at some predetermined destination, but to utilize reading, writing and speaking skills so that our understanding of the world is progressively enlarged." The Zahlers continue with: "Knowing the facts is just the beginning. Being able to link them together, to discard one in favor of another, to synthesize them into a personal philosophy—that is the ultimate measure of literacy" (p. xiii). Also, they point out Chall's (1983) notion of levels of literacy, a concept that will be useful later in this chapter when a definition and model for technological literacy is synthesized.

It must be remembered, however, that "basic literacy is a prerequisite to scientific or technological literacy" (Miller, 1986, p. 3). Given that technological literacy may well serve a motivational function, it is most plausible that technological literacy could also operate as a requisite to scientific literacy. Therefore, to this author the concepts relate as shown in Figure 7-1. DeVore (1987) cited the conclusion (which was based upon a review of recent national reports) of Atkinson, the former NSF director "that technological literacy needs to be a part of general literacy." DeVore also cited the Coleman Report that stressed "technological literacy is quite different from scientific literacy and mathematical literacy" (p. 12).

NATURE OF TECHNOLOGY

Technology—that mysterious stranger yet omnipresent colleague. We talk as if we know you well—yet do we? This author is inclined to agree with Frey (1987) who suggests that many "proceed as though the

reader shares some commonsense notion of technology (p. 7)" when really there is little evidence of this. Frey also points that the definition of technology cannot occur from within technology. He claims this is a question **about** technology and infers that it needs to be addressed from "outside" technology, e.g., from philosophy. Because of this, considerable effort was invested to secure sources outside the technology profession, both for this chapter and for the entire yearbook.

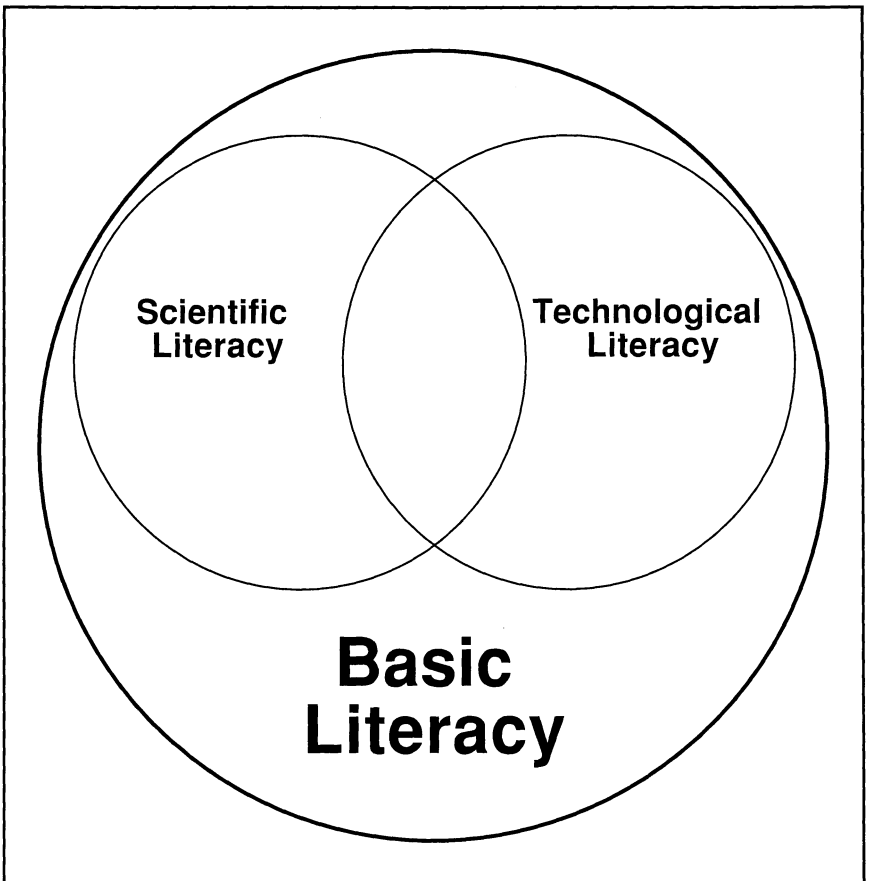


Figure 7-1. The context of technological literacy.

Perhaps most notable among the problems in the meaning of technology is its confusion with science. The distinction that Skolimowski (1966) raised "science concerns itself with what **is**, technology with what **is to be**" (p. 374) does not seem prevalent in the public's consciousness. For example, MacPherson, (February 17, 1986) in Newark's *The Star-Ledger*, states that "when we think of the science that is part of our lives, what we are really thinking of is technology. Our microwave ovens, our ability to watch the Olympics via satellite, our telephone systems, these are the physical applications of our science ... Its [technology's] notable absence from our public school curriculum is irresponsible. Yet it's been missing for so long that technological illiteracy has begun to loom as a general societal problem."

Technology's Context

Whatever technology is, it occurs in a context, i.e., an environment. This environment forms a backdrop against which technology is viewed. As such the context is also useful because it identifies things that **aren't** technology. Were they, they would of course be classified as technology.

The AAAS, in their Project 2061, viewed life in three planes: The technical plane, the social plane, and the views and values plane. Better known to the technology education profession are DeVore's (1987, p. 31) four basic systems (ideological, sociological, ecological, technological) that form technology's context. Kozak (1989, p. 1) essentially adapted DeVore's view by identifying the entirety of the natural and man-made environment to include three "human adaptive systems: ideological, sociological and technological" as shown in Figure 7-2.

Another approach to establish the context of technology was followed by Kasprzyk (1980), Smalley (n.d.) and Dyrenfurth (1984). These writers depicted technology against a backdrop of other disciplines.

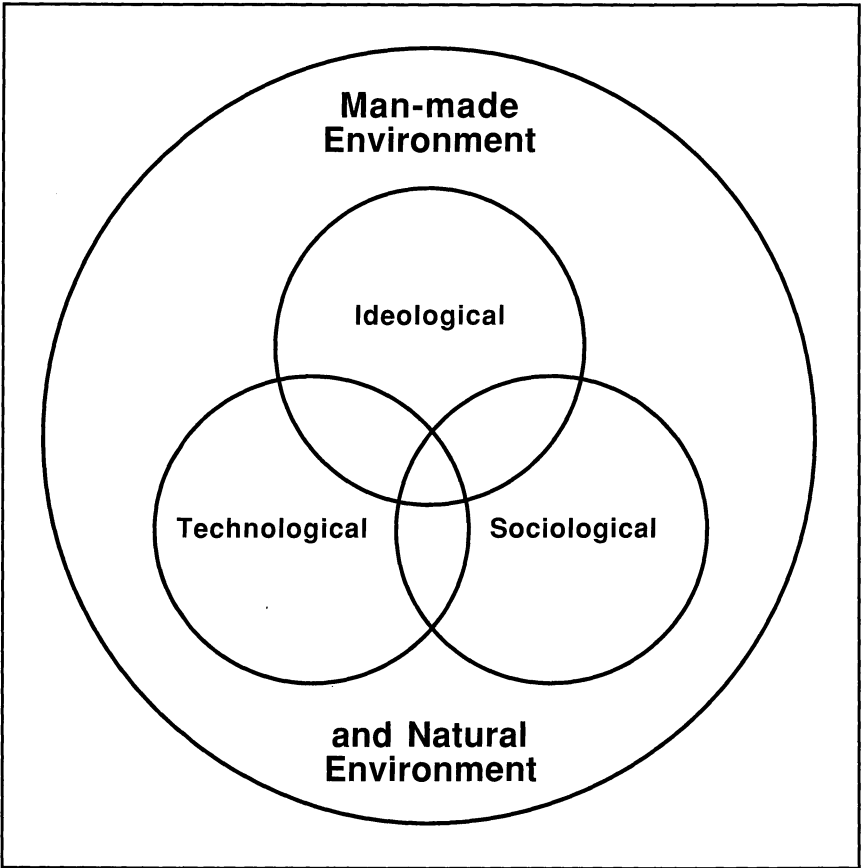


Figure 7-2. Technology's context (Kozak, 1989).

For example, Smalley (n.d.), in an unpublished paper entitled "The matrix for technology," used the rubric shown in Table 7-1, as adapted from Kasprzyk (1980), to clarify the context of technology and to add meaning to the term itself.

Forms of work	Aims	Consequences
Science	To know why	Theories or laws
Technology	To know how	Rules
Technic	To do or produce	Product or service

Table 7-1. Technology's context (Smalley).

Building on this approach, this chapter's author in his National Center for Research in Vocational Education (NCRVE) monograph (Dyrenfurth, 1984) expanded the context as shown in Table 7-2.

Human Endeavor	Characteristics	Application Arenas
Religion	Divine wisdom	Theology •
Science	Explanation of nature	Chemistry Physics •
Technology	Doing, applying rules and experience in solving practical problems	Annihilation Healing Industry Agronomy Engineering •
Philosophy	Systematic thought	Metaphysics Epistemology Logic Ethics •
Social Science	Behavior	Sociology Psychology Anthropology Pedagogy Andragogy •
<p>Note: A preliminary and tentative view of the context of technology is shared in this illustration. It presents a series of categories of human endeavor in the left column. The key characteristic(s) of each endeavor is(are) listed in the middle column. Finally sample application arenas for each category of endeavor are listed in the right column. In each column, the items listed are intended to be illustrative rather than exhaustive (Dyrenfurth, 1984).</p>		

Table 7-2. Technology's context (Dyrenfurth).

Technology's Arenas / Fields / Systems

Another way of lending intelligibility to technology is to systematize the arenas or fields in which it is used. Many examples of taxonomies exist to prove the popularity of this approach. Relatively few however

appear to have documented overt attention to the rules of taxonomic structure and logic. Nevertheless, an overview of their findings evidences key directions that may be pursued and subsequently systematized. Although Table 7-3 suggests considerable congruence in this matter, it should be noted that at least some dissent exists. For example, Barnes (1986) cited LaPorte's suggestion that our profession discard categories such as production, communication and transportation in favor of ones that reflect all of technology.

Communication, production, transportation, construction, energy & power, materials & processing, agriculture, health/medicine, and information are the primary technology application fields/arenas that emerged from the literature. As presented here, they represent a compilation, not a taxonomy. However, disregarding their overlap, it seems that there is little purposeful human behavior that would not fit into one or another element of this rubric.

Field/Arena	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Agriculture, food, renewable resources			
Biological, biotechnology, life					
Commerce, industry				.										.	
Communication
Computer control															.
Construction, structures, shelter
Energy & power, utilization	
Environment														.	
Goods							.								
Health, medicine				
Information					
Materials & processing, materials			
Military				.										.	
Natural phenomena							.								
Physical, physical technology				.	.										
Production, manufacturing
Service															.
Transportation

Sources: 1=Todd, 1987; 2=Illinois Plan, 1984; 3=New York State Education Department, 1984; 4=Dyrenfurth, 1982, 1984; 5=Williams et al., 1985; 6=Vocational Technical Education Service, 1988; 7=Cross & McCormick, 1986; 8=Gradwell, 1988; 9=Kozak, 1989; 10=DeVore, 1973; 11=Arp, 1989; 12=Jones, 1984; 13=Rutherford (in Bensen, chp 6); 14=Erekson (in Barnes & Erekson, chp 5); 15=Chamot (in Barnes & Erekson, chp 5)

Table 7-3. Technology's application arenas/ fields.

In this author's PATT-III paper (Dyrenfurth, 1988), it was suggested that examination of the various arenas in technology reveals that in

each of the application arenas, the process of "doing" technology is quite similar. Consequently it became feasible to treat the application arenas in another manner. Because each engenders unique perspectives, the application arenas were considered as a context or frame of reference through which any model of technology or technological literacy might be viewed. This approach is illustrated in Figure 7-3. These perspectives can serve as screens through which the model can be seen. This removes the settings/application arenas from the model itself and thus makes it more generic.

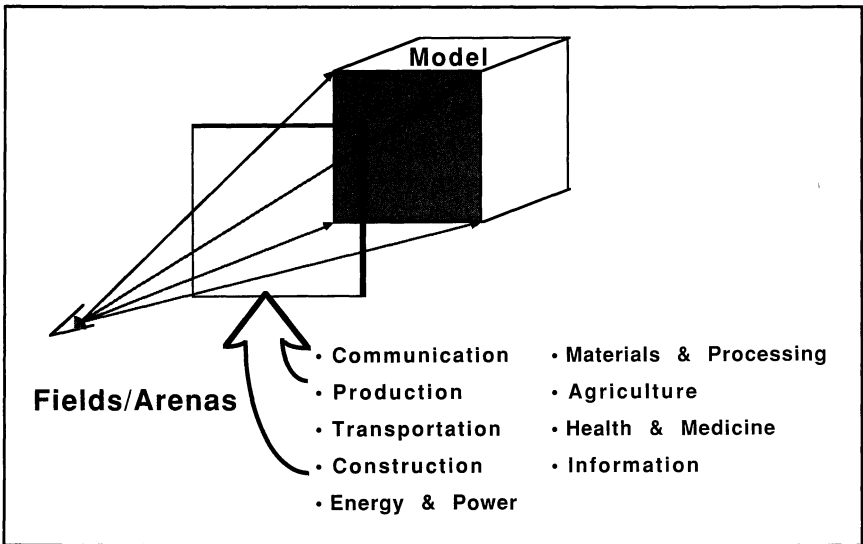


Figure 7-3. Technology's application arenas as frames of reference.

Definitions of Technology

The preceding sections have described some, but certainly not all, of the contexts, arenas and components of technology. The author's intent was to depict the scene more than to arrive at a consensus definition of technology. That will remain for this section to accomplish. In it are presented the definitions of authorities, both within and outside the technology education profession, as well as appropriate discussion. This concludes by presenting an operational definition of technology that served as a working guide for the rest of this chapter.

Shown in Figure 7-4, the definitions range from the terse (Smalley, n.d.) through the suspiciously tongue-in-cheek (Heller, 1982), to the dangerously all-encompassing (Commission on Technology, 1987).

Technology is:

- the "scientific study of the practical or industrial arts" (Murray, cited in Pytlík, Lauda & Johnson, 1985)
- "a description of arts, especially those which are mechanical" (Crabb, cited in Pytlík, et al. 1985)
- taken to be "the making and using of artifacts in the most general sense..." (Mitcham & Mackey, 1972, p. 282).
- "the knack of so arranging the world that we don't have to experience it" (Heller, 1982)
- "any systematized practical knowledge, based on experimentation and/or scientific theory, which enhances the capacity of society to produce goods and services, and which is embodied in productive skills, organization, or machinery." (Gendron, 1977)
- "a study of the technical means undertaken in all cultures (a universal), which involves the systematic application of organized knowledge (synthesis) and tangibles (tools and material) for the extension of human faculties that are restricted as a result of the evolutionary process." (Pytlík, Lauda & Johnson, 1985, p. 7)
- "a set of standardized, repeatable operations that regularly yield predetermined results. This includes 'software' systems ranging from methods of housekeeping to the use of street addresses as well as 'hard technology' of open-hearth furnaces." (Price, 1978)
- "knowing how to do something from the rules, sometimes from scientific theories, sometimes from pragmatic experience (technic)." (Smalley, n.d., p. 20).
- "a social process in which abstract economic, cultural, and social values, shape, develop and implement specific artifacts and techniques that emerge from the distinct technical problem-solving activity called engineering which is embedded in that process." (Cutcliffe, 1981, p. 36).
- "both a creative, constructive and/or a destructive process by which humans employ tools, resources, machines, and systems to achieve personal identity and to enhance their control over the human, animal and physical environment." (Ray Merritt cited in Smalley, n.d., Matrix for Technology).
- a product of mathematics, science and engineering ... "Technology consists of tools, devices and techniques that have been created to implement ideas born of science and engineering. (p. 73) (Coleman Report cited in DeVore, 1987, p.13)
- "practices in order to test or refine theories of efficient action which can only be derived from practice. Knowledge (ology) of practice (techn) is technology" (Lux, 1983, p. 1). It is praxiological knowledge—the knowledge of practice!
- "the 'know how' and creative process that may utilize tools, resources and systems to solve problems to enhance control over the natural and man-made environment to alter the human condition" (UW-Stout's Technology Study Committee cited in Smalley, n.d., Matrix for Technology).
- "the know-how and 'creative process that may utilize tools, resources and systems to solve problems to enhance control over the natural and man-made environment with an endeavor to improve the human condition." (UNESCO, November 1985, pg. 3)
- "the rules for efficient action." (Smalley, n.d., Matrix for Technology).
- "the science concerned with: 'the study of the creation and use of adaptive systems; tools, machines, techniques, resources, energy, information and human organization, and the relation of the behavior of these systems and elements to people, their societies, the environment and the civilization process.'" (DeVore, 1987, p. 28)
- "the application of knowledge to satisfy human needs and wants, and to extend human capabilities." (Commission on Technology Education, 1987, p. 9)
- "viewed as object - thing; as process - doing, making & using; as knowledge and as volition." (Frey, 1987)
- "a disciplined process using resources of materials, energy and natural phenomena to achieve human purpose." (Gradwell, February, 1988).
- "a synergistic nuemenon that occurs through the interaction of knowledge, thinking processes, and physical means while attempting to satisfy human wants and needs." (Johnson, 1988)
- "the manipulation of the environment to meet the basic needs for survival and then to extend human potential. Simply stated, technology is the application of whatever knowledge is appropriate in a given situation for the extension of human capabilities." (Kozak, 1989, p. 1)
- "The application of accumulated human knowledge to the transformation of resources, through the use of tools, for the purposes of meeting human needs or solving problems." (NYS, 1984, p.6)

Figure 7-4. Technology's definitions.

They include highly abstract ones such as Johnson's (1988) and Frey's (1987) and concrete historical ones such as Murray's and Crabbs' cited by Pytlik, Lauda & Johnson (1985).

Characteristics & Processes of Technology

A series of comparative and synthesizing tables were prepared to summarize the components and processes highlighted by various authors as being central to technology. Several key understandings emerged from these analyses. Their compilation represents a synthesis, albeit incomplete, but semi-comfortable to this author at least.

Among the observations derived from Table 7-4's presentation of a synthesis of technology's components is the recognition that people are a necessary co-requisite to technology. While one can have the artifacts of technology without people, one cannot have technology without people. People are involved with the tangible artifacts (tools, machines, materials) of the world. Mention is often made of information and problem-solving (the latter strongly suggestive of purposeful activity). In addition, the systems model (input \Rightarrow process \Rightarrow output and feedback) was frequently mentioned as was the energy, power

Components of Technology	Authors
Energy	Todd, 1987; Gradwell, 1988; Kozak, 1989; Arp, 1989
Feedback	Kozak, 1989
Humans	Todd, 1987; Cross & McCormick, 1986; Kozak, 1989
Knowing	Cross & McCormick, 1986
Knowledge, information	Todd, 1987; Kozak, 1989; Arp, 1989
Materials	Todd, 1987; Gradwell, 1988; Kozak, 1989; Arp, 1989
Natural phenomena	Gradwell, 1988
Ordered systems	Cross & McCormick, 1986
Outputs	Kozak, 1989
Problem solving	Hodges & Lichter, 1980
Processes	Todd, 1987; Gradwell; 1988 Kozak, 1989
Purpose	Gradwell, 1988
Resources	Kozak, 1989
Skills	Todd, 1987
Tools, machines	Todd, 1987; Cross & McCormick, 1986; Kozak, 1989
Understanding	Cross & McCormick, 1986
Values	Cross & McCormick, 1986

Table 7-4. Technology's components.

and control needed to enable the activity. Other authors, and some of the preceding, have gone beyond merely listing the arenas within which technology operates. They have attempted to identify the components that make up or are involved in technology.

Beyond technology's components, as identified in Table 7-4, are even more important sets of commonalities. These are the processes that various authors use to characterize the "doing" of technology. An overview is presented in Table 7-5.

Processes of technology	Authors
Assessing	Bensen, chp. 6; Dyrenfurth, 1988
Communicating	Erekson, chp. 5; Dyrenfurth, 1988
Controlling technology	Erekson, chp. 5; Dyrenfurth, 1988
Creating	Cross & McCormick, 1986; Barnes, 1988b, Pytlik et al., 1985; DeVore, 1980
Decision-making	Erekson, chp. 5
Designing	Cross & McCormick, 1986; Raat, 1987; Barnes, 1988b
Doing	Bensen, chp. 6; Dyrenfurth, 1988
Enterprise	Barnes, 1988b
Experimenting	Dyrenfurth, 1988
Futuring	Dyrenfurth, 1988
Human activity	Raat, 1987
Information accessing	Cross & McCormick, 1986; Dyrenfurth, 1988
Innovating, inventing	Erekson, chp. 5; Barnes, 1988b; DeVore, 1980
Interacting with social systems	Bensen, chp. 6; Goldman, 1984
Knowing	Bensen, chp. 6; Dyrenfurth, 1988
Living environmentally soundly	Bensen, chp. 6; Cross & McCormick, 1986
Living safely	Bensen, chp. 6
Modeling, simulating	Dyrenfurth, 1988; Cross & McCormick, 1986
Organizing	Cross & McCormick, 1986; Fleming (Scarborough), chp. 3
Problem solving	Cross & McCormick, 1986; Barnes, 1988b, Raat, 1987; Popenoe, 1971; NYS Ed. Dept., 1984
Research & development	Barnes, 1988b
System structuring, synthesis	Cross & McCormick, 1986; Dyrenfurth, 1988
Systems analysis	Dyrenfurth, 1988
Thinking processes, analytical thinking	Pytlik et al., 1985; Erekson, 1989
Utilizing adaptive means	DeVore, 1980

Table 7-5. Technology's processes.

A highlighting of selected excerpts from the literature will usefully augment the syntheses presented in Tables 7-4 and 7-5. It will add the nuances and color that individual perspectives make possible. To begin with the earliest, Pytlik, Lauda & Johnson (1985) included in their review of the characteristics of technology, a compilation of their literature findings:

- the means by which man controls, adapts to, or modifies his environment. (Spier, 1968, p. 131; Arensberg & Niehoff, 1971, p. 498)
- The information, techniques, and tools with which people utilize the material resources of their environment to satisfy their various needs and desires. (Lenski, 1974, p. 498)
- a special kind of knowledge which is directed towards practical applications in the physical and social world. (Popenoe, 1971, p. 64)
- "...engine of change" (Toffler, 1970, p.25)
- How things are commonly done or made (Singer, Holmyard, & Hall, 1954-84)
- Analytical thinking, creativity, extensions of the human body

Pytlik et al.'s well done synthesis serves as an effective base from which to build a clear understanding of technology. This however, needs to be augmented with additional detail. For example, Frey (1987), in referring to Hannay & McGuinn's view of technology as "a distinctive form of human cultural activity" (p. 26), reported that they identified as general dimensions to technology:

- | | |
|----------------------------|--------------------------------------------------------|
| • Outputs or products | • Mental sets of the activity's practitioners |
| • Function(s) | • Socio-cultural-environmental contact of the activity |
| • Resources | |
| • Feature of the processes | |

This adds the system model concept to Pytlik et al.'s base and it also stresses the socio-cultural-environmental impacts of technological activity. Erikson (1989), noting a potential pitfall, stated "because technology, as viewed in this paper, exists only in the mind, there must certainly be something physical that leads to the satisfaction of human wants and needs. This physical phenomenon is a result of technological activity. Technological activity is composed of six distinct components: (1) Values, (2) Knowledge, (3) Thinking processes, (4) Physical means, (5) Extension of human capabilities, and (6) Impacts" (p. 5).

DeVore's (1980) definition of technology must necessarily be highlighted considering his well deserved position of eminence in the profession. He states "The study of the creation and utilization of adaptive

means, including tools, machines, materials, techniques, and the technical systems, and the relation of the behavior of these elements and systems to human beings, society, and the civilization process is the field of study known as technology" (DeVore 1980, p. xi).

Chapter Author Perspectives on Technology

Technology—the means to fuel our economic engines (Stevens, chapter 4) is not the mysterious, unknown entity that some would suggest. Indeed, this yearbook's chapter authors apparently had little problem reaching/adopting a satisfactory sense of surety about this concept. These senses ranged from very basic views of application arenas, e.g., manufacturing, communication, service (Stevens, Chapter 4); to the more process-oriented views of Johnson's Project 2061 Technology Panel report cited by Bensen in his chapter (6). The latter included the processes of knowing, doing, judgement/assessing, interacting with social systems, living safely, and living environmentally soundly. This process-oriented view of technology was echoed by Erikson (Chapter 5) who included and highlighted the processes of controlling technology, communicating and decision making.

The content/application arena perspective of technology is pointed out in Scarborough's (Chapter 3) citing of Fleming's view: Ordered systems, people, organization, living things and machines. Rutherford's view, stemming from the AAAS's Project 2061 report, contrasts by using the organizers of: Agriculture, materials, manufacturing, energy sources, energy use, communication, information processing, health technology according to Bensen (Chapter 6). Differing perspectives are also evidenced by Chamot's (Chapter 5) categories of: Manufacturing, construction, power energy, materials, service, communication, and computer control; and Erikson's (Chapter 5) use of: Energy & power, materials, biological applications, food, renewable resources, health, communication and information, transportation, environment, commerce, military.

Although mere linguistic analysis reveals the difference in these various perspectives of technology, it is this author's point that in essence, these views of technology are much more alike than different. They all view technology in terms of artifacts being used in various artifact-intensive arenas. Additionally the notion of the existence of characteristic technological processes was not gainsaid by any author.

For the purposes of achieving closure, this author then synthesized a definition that serves as a guide for subsequent work in this chapter.

Technology is the human activity² that purposefully addresses the satisfaction of human wants or needs³ via the use of physical means⁴ that are extensions of human capabilities.⁵ Typically technological activity involves one or more characteristic processes⁶ (such as those presented in Table 7-5, e.g., problem solving, enterprise, creativity,...) and it is set in a context that invariably involves value- and moral-laden questions.⁶

NATURE OF TECHNOLOGICAL LITERACY?

Up to here, this chapter has explored the meaning of literacy and technology. In particular, it documents the expansion of literacy to include a functional dimension (beyond merely reading and writing), as well as the emergence of context-sensitive versions of literacy such as scientific, cultural, economic, agricultural, computer and technological literacy. What remains now is to explore the notion of one of these, namely technological literacy, in depth. This will be followed by the presentation of existing models of technological literacy and the advancing of a synthesized model for technological literacy.

Methods of Ascertaining Definitions of Technological Literacy & Confusion About Technological Literacy

In 1987, DeVore lamented "Unfortunately with all the effort directed toward the issue there has been little agreement on what technological literacy is or how to attain it" (p. 1). In fact, he documents the general

²Frey (1987), Raat (1987), Erikson (1989)

³Erikson (1989), NYS Education Department (n.d.)

⁴Erikson (1989), Barnes (1988b), Pytlik et al. (1985), NYS Education Department (n.d.), DeVore (1980)

⁵Erikson (1989), Pytlik et al. (1985)

⁶Processes that range from creativity, innovation, R&D, invention as highlighted by Barnes (1988b) and Cross & McCormick (1986); through enterprise, Barnes (1988b); to problem solving as prominently featured in many works among them, NYS Education Department (n.d.), Raat (1987), Barnes (1988b), and Cross & McCormick (1986).

⁷Note Pacey's (1983) questions of the neutrality of technology, Erikson's (1989) and Barnes (1988b) mention of values. Pacey (1983) in his *Culture of Technology*, makes the point that contrary to popular wisdom technology is not "culturally, morally, or politically neutral." Technology to Pacey is more than machines and tools and it is infused into the very fiber of our lives. He is concerned about peoples' reluctance to view technology in this way.

confusion about both it⁸ and technology. To address the confusion, this chapter's author again began by looking at other peoples' methodology for assistance in learning how to define concepts. In general, most were found not even to have documented their approach. Instead, they just presented the results of their approach, i.e., the definition/description of technological literacy. Many others did not even do this. They just used the term, apparently with the assumption that its meaning was sufficiently understood to make it useable. Epistemologically this is unacceptable. Given this, the author corresponded with several leading colleagues for help in this matter.

David McCrory, one of those who responded, suggested that one way of identifying the meaning of a term is to analyze how it is used by others "who are thinking and writing about it, then deduce some meanings from the findings." He also pointed out the bipartite component to the term and that both literacy and technology have dynamic meanings (McCrory, May 5, 1983). Later, Paul DeVore (April 20, 1987), in a personal letter response to the author's inquiry, stated "I do not believe it is possible to obtain a 'convergence on the concept of technological literacy' unless one first addresses the question of social purpose and then by inference derives the nature and characteristics of the technical means required to attain and maintain the social purpose."

Both of these inputs were valued, and indeed, as this chapter demonstrates, were used as guides for action. Additionally, content analysis and logical reasoning, both inductive and deductive, were employed. For example, collateral concepts such as scientific and agricultural literacy were analyzed to identify transferable components.

Science / Computer / Agricultural Literacy

What then is scientific literacy? Or computer literacy? Or agricultural literacy? For operational purposes of keeping this chapter's length somewhat manageable the author arbitrarily vetoed any treatment of the plethora of proselytizing computer literacy literature. Scientific literacy on the other hand was another matter. Some of the best minds in the country address this issue.

Many of these sources, e.g., the Coleman Report (DeVore, 1987), Atkinson (1984), the former NSF director, and Miller (1986) documented that scientific literacy is viewed as something "conceptually dis-

⁸For purposes of this discussion, technical literacy is considered indistinguishable from technological literacy.

inct" (Miller 1986, p. 5) from technological literacy. Additionally, Miller pointed out that "as a term, the roots of scientific literacy are longer and deeper than technological literacy and have been described elsewhere" (Graubard, 1983).

But what **is** scientific literacy? Miller (in Rothman, 1986, p. 14) defined scientific literacy as "an understanding of the norms of science and knowledge of basic scientific concepts." Earlier however, Miller (1983ab) had published a much more definitive view of scientific literacy. He wrote: "there is an important definitional parallel, however, between basic literacy and scientific literacy. If basic literacy refers to the ability to read or write at a level that allows an individual to function in his or her society, then scientific literacy should be defined as the ability to read, comprehend, and communicate about science at a level that would allow an individual to function effectively in a scientific culture like our own."

Both of these are still rather simple definitions. More useful is Johnson's (1989), who provides details that communicate much more of his sense of the term: "scientific literacy must be more than the understanding of a few basic principles in the biological or physical sciences. Rather, it must encompass the ability to apply an understanding of science principles, methodology, capabilities, and limitations to the wide range of decisions students will face both as citizens and as professionals." Note that this refers primarily to decisions, not actions. Miller (1986) also noted the need for a better definition and he suggested scientific literacy to have three dimensions, a(n): (a) understanding of the scientific approach to evidence and theory building, (b) knowledge of basic terms and constructs, and (c) understanding of how science and society impact on each other. Rothman (1988), a frequently published science journalist, complemented this definition of scientific literacy with:

- knows everyday science facts
- understands scientific principles
- applies basic scientific information
- analyzes scientific procedures and data
- integrates specialized scientific information

The literature surrounding agricultural literacy presents themes similar to those of scientific literacy, although there is much less of it and it emerged much later, primarily from the National Research Council's study report. In reporting on this, the American Vocational Association's (1988) *Legislative Brief* noted that the National Research Council called for increased levels of agricultural literacy for **all** stu-

dents in America. However, they spoke of it more in terms of what students should **know** than what they should **be able to do**. Walker (1988) citing the same report, repeated the mistake in stating that "The nation needs to shore up its knowledge base in agriculture ... exposing all students... to some kind of systematic instruction in the field" (p. 1). He cited the report's call for "agricultural literacy" because "agriculture is too important a topic to be taught only to the relatively small percentage of students considering careers in [it]" (p. 1). As one way to accomplish the goal, Mr. Aldrich, the authoring committee chairman, urged "that knowledge about the field be integrated into current coursework in science, social studies, mathematics, and other subject areas" (p. 9). More substantively, the description of an agriculturally literate person was "one who has an understanding of the food and fiber systems, including historical developments and current economic, social, and environmental issues. The definition would also include, Mr. Aldrich said, enough knowledge to 'make informed personal choices about diet and health' and 'care for outdoor environments'" (Walker, 1988, p. 9).

Content analysis of these views on scientific and agricultural literacy identifies several important characteristics with implication for technological literacy. These include:

- understanding of basic principles and processes
- ability to **ap** principles and processes
- facility in communicating about the discipline
- sense of the interaction among the discipline, society and its values
- awareness of historical evolution of the discipline
- links between the discipline and economics
- career implications of the discipline

Technological Literacy

The question, "What is technological literacy (TL)?" will be answered using three sections. (a) TL: The descriptive characteristics approach, (b) TL: The competency list approach, and (c) TL: The graphic approach. The first section presents a discussion of the descriptive characteristics used to depict technological literacy. It provides key definitions and descriptive characterizations from the rapidly growing literature referring to technological literacy. The second section highlights authors whose approach to technological literacy was that of establishing the competencies a technologically literate person would

be able to demonstrate. The third section presents graphic models used to depict the concept.

TL: The Descriptive Characteristics Approach

Definitions always represent one way of establishing the meaning of a concept. This author actively searched for exemplars of such definitions and they are presented in Figure 7-5. Other meaningful insights were gained by noting descriptive remarks and characterizations people made when talking about technological literacy or closely related topics. Note for example, Rehg's (1986, p. 80) comment about the basics for the future:

Education for the professionals who will work in manufacturing automation starts with the basic principles that form the groundwork of an engineering or technology education. In addition, their training must include sensors, interfacing, factory communication networks, manufacturing process, robots, programming and an introduction to the hardware and software used in automation systems ... A strong base in communications, problem-solving, basic technical and automation principles, and team problem-solving must be a part of the educational process for individuals who are working, or who will work, in highly automated factories.

Although Rehg never mentions technological literacy in this citation, it is clear that he is referring to it, or at worst, to something very much like it! Similarly, the Omaha, Nebraska, *Sunday World-Herald*, Section G (p. 1), carried a story that pointed out the positive sides of a "new workforce." This group "has learned new skills and adapted to new working conditions;" among the former are "reasoning skills, higher language skills, math and analytic skills" and it has integrated them into a whole range of duties.

Paul DeVore (April 20, 1987), in a personal response to the author's inquiry, stated "There are many kinds of technological literacy. Those in our field generally focus on the ability to make or construct. But if we are to prepare citizens for a democratic social order we need citizens who can assess also."

Technological literacy is:

- "an understanding of the application of science and engineering to the solution of concrete problems." (Miller, 1986, p. 5).
- "the possession of a broad knowledge of technology, together with the necessary attitudes and physical abilities to implement the knowledge in a safe, appropriate, efficient, and effective manner. Technological literacy requires that one be able to perform appropriate tasks using the tools, machines, materials, and processes of technology. Industrial technological literacy, a subset of technological literacy, may be defined as 'the ability to understand, appreciate and efficiently make and use the man made world'" (Lux, 1978).
- "the qualities which permit a person to interact successfully with technology. These include: consumer/user skills, technical skills, the ability to assess the impact of technology on everyday life, the ability to understand issues in a democratic technological society, the ability to apply conceptual knowledge to the solution of technical problems, and a knowledge of career opportunities in technologically-related fields of endeavor" (NYS, 1984, p.5).
- "an understanding of the systems of technology" (Jones, 1984, p.8).
- "the ability to function as knowledgeable citizens in our increasingly technological world" (Peckham, September, 1989).
- the creation, use and control of technical means is embedded in the social, economic and political fabric of our society" (Bowden, 1982, p. 9 in DeVore, 1987, p. 13).
- "the issue is the understanding and control of the behavior of technological systems as a major component of social systems and as a critical factor in cultural change and disruption within societies" DeVore (1987, p. 22).
- intended to "control technical means by intelligent socially sensitive human beings" (DeVore, 1987, ITEA).
- technology and the teaching of values. The AAHE Bulletin, pp. 8-10, cited the 1983 Atlantic Council Policy paper which stressed "that today's youth 'must understand the need, uses, and limitations of technological knowledge and the challenges to traditional values technology can pose. How can they use technology for humane purposes and not be overshadowed by it?'" (Billington, December, 1985, p. 8).
- to "integrate work and life," to "provide flexibility and mobility of both skills and of geography," and to find a "set of meaningful values" (DeForge, 1981).
- an ability to experience, observe, examine, draw and design things for and from the environment. As a result, young people should be able to:
 - understand the steps in a process
 - develop mental images/ideas into forms that they can see and react to
 - look at the physical world in alternative ways (Smalley, n.d.)
- "the possession of a broad knowledge of technology together with the attitudes and physical abilities to implement the knowledge in a safe, appropriate, efficient, and effective manner. Technological literacy requires that one be able to perform tasks using the tools, machines, materials and processes resulting from technology" (Dyrenfurth, 1984).

Figure 7-5. Definitions of technological literacy.

A somewhat different characterization was used by Markert (1985). In her research investigating dimensions of general life satisfaction, she identified a factor, one of five, she termed technology accordance. According to her, it "focuses on the respondents' opinions regarding the impact that 'technology' has on the quality of their lives in general" (p. 8). Analysis of her items by this author identified the following topics in her 25-item scale: Computers & electronics, environmental concerns, nuclear power/energy issues, technological information

input, corporate environment, defense issues, genetic/medical issues, space/transportation, societal control of technology/change, automation, home environment and technology assessment.

Other authors have suggested, "focussing technological literacy on the creation, use, behavior, and relational factors of adaptive systems ..." (DeVore, 1987, p. 29) and that this could serve as a bridge between academic knowledge, theory and practical application (Peckham, September, 1989). Larry Hatch (1985), in his dissertation, identified three dimensions to technological literacy: practical, civil and cultural. Similar in intent, Billington pointed out the three values that can serve as the base for modern life. These are efficiency (truth and reverence for facts), economy (politics in society) and elegance (imagination). He also pointed out the need for maintenance skills as part of the demands of the future. (December, 1985, pp. 8-10).

Analogously, technological literacy **necessarily requires** the ability to **do** technology, that is, to use it and not merely to **recognize** technological processes. Technological literacy requires more than just the ability to **identify** technological components or to be **aware** of technology's effects. Although these characteristics; recognizing, identifying, and awareness; are important and necessary characteristics of technological literacy, **without the ability to do**, they are unfortunately **not** sufficient. The ability to do necessarily involves skill to some extent. Doty (1979) pointed out the central nature of skillful action as an essential part of technology—a point often minimized by proponents of the analytical, subject-matter-focused approach of many industrial arts reformers. Note, however, that skill exists in a continuum ranging from non-skilled up to artistic proficiency.

The concept of a generalized understanding of, and capability with, technology has roots that Árp (1989), traces to works of Beckmann (1806), Verein Deutsche Ingenieure (1977) and Wolffgramm (1978). He includes within this concept, an ability to use the systems approach, analysis pursuant to the components of technology, interfacing to related disciplines, tracing flows, and learning strategies. To these, Booth (1989, p. 117) adds the content dimension, i.e., which fields are exem-

plified by technology, by pointing out that "a sound initial understanding of technology applications is founded on a knowledge of:

- i. energy forms and transformation
- ii. materials and testing
- iii. hardware of technology
- iv. environment
- v. communication"

Technological literacy possesses yet another important characteristic. This suggests that one can possess technological literacy at various levels, just like reading. For example, "Conceptually, I would view technological literacy as a continuous or internal [sic] variable and would expect that we could identify some threshold level" (Miller, 1986, p. 5). Erikson (1989) noted that Frey's (1987) four approaches to technology contained in them a hierarchy that this author sees as having implications for technological literacy to contain levels as well. Dyrenfurth (1984), had earlier used the concept of "orders" to make the levels of technological literacy explicit as shown in Figure 7-6.

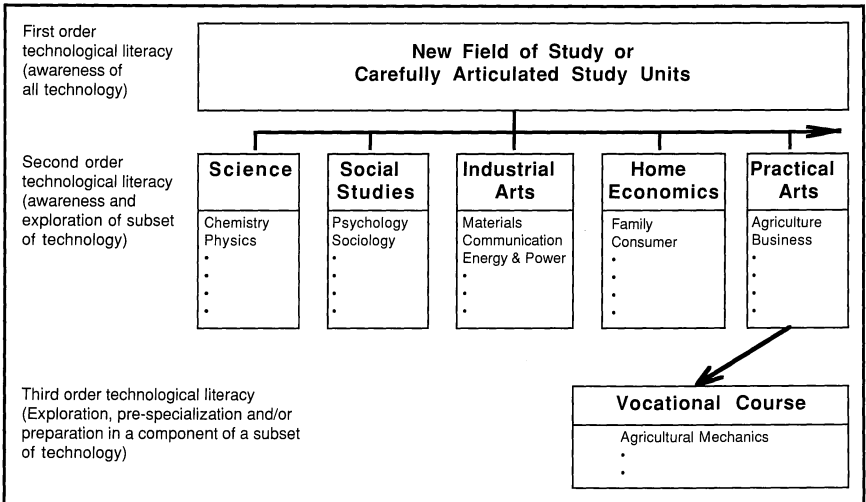


Figure 7-6. Orders of technological literacy.

Later this evolved to a model that associated levels with characteristic positions/work roles in life as shown in Figure 7-7.

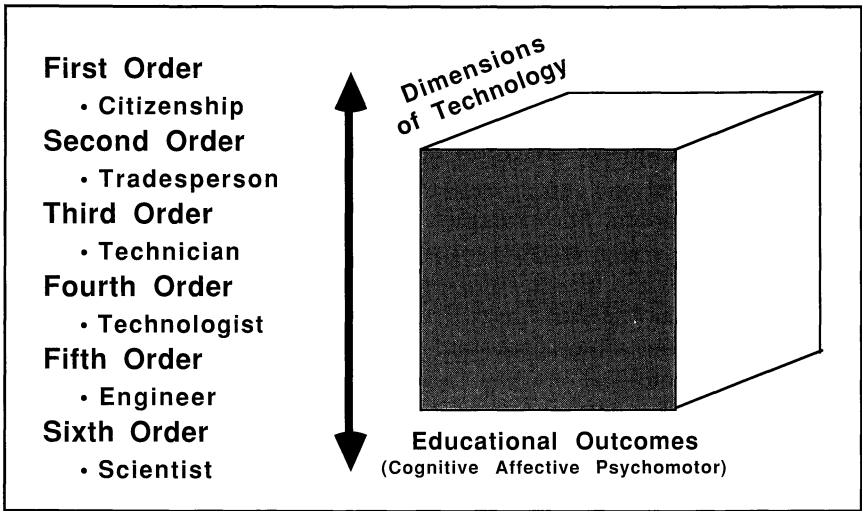


Figure 7-7. Levels of technological literacy.

TL: The Competency List Approach

Many different types of authors generated work about technological literacy. They included universities⁹, institutions¹⁰, individuals¹¹, international agencies¹², state departments¹³, federal research agencies¹⁴, and state government consultants¹⁵. Conspicuously absent, however, were representatives of the private sector.

Both national and international studies were observed to use the competency listing approach to clarifying technological literacy. The time span covered by these sources ranges from The Engineering Concepts Curriculum Project (1971), Deforge's pioneering international work (1972), and Halfin's milestone dissertation (1973) to the recent

⁹*Science and Technology for Tomorrow's World*, Exeter conference (1985)

¹⁰National Academy of Science (1984), NCRVE (Dyrenfurth, 1984)

¹¹Halfin (1973), Foster & Perreault (1986), Bell et al. (1982), Smalley (1982)

¹²Council of Europe (Deforge, 1972, 1981), UNESCO (1983, 1984, 1985)

¹³New York State Education Department (n.d.)

¹⁴Northwest Regional Educational Laboratory (1984)

¹⁵Rosenfeld (1986, 1988)

work of Foster & Perreault (1986), and Grodzka-Borowska & Szdlowski (1989). No trend emerged except for an apparent but small increase in the frequency of mention of the concept in more recent times. Additionally, the variety of authors speaking to technological literacy has increased significantly. Because no satisfactory categorization system was found in the literature, this author chose to present selected exemplars of the competency list approach to defining technological literacy.

The Engineering Concepts Curriculum Project's list may very well be the conceptual ancestor father of the definitive technological literacy competency list. This project's competencies are presented in Figure 7-8.

Foster & Perreault (1986) conducted a survey to identify perceptions of technological literacy. Their ten highest ranked competencies are shown in Table 7-6 and they characterize a prevalent view of technological literacy. These researchers summarize by characterizing the technologically literate person as having "a broad understanding of technology in reference to its many and varied impacts on consumerism, politics, culture, values, work and basic societal institutions..." They are "generally conversant in technology, able to communicate effectively in technological areas of interest, able to use the design process in the solution of technical problems," able to "use appropriate terminology" and are "knowledgeable of the industrial applications of computers. They utilize their knowledge in matters of further education and career selection..." They use science and mathematics mainly in terms of applications and "to objectively assess technological options and solve problems analytically. The technologically literate possess broad understandings of systems, processes and principles. Such understandings enable them to appreciate the strengths and limitations of technology as it is used to meet human needs. They recognize that the control of technology is multifaceted and systems oriented" (p. 58).

A Technologically Literate Person:

- Can use the decision-making process effectively.
- Can make valid predictions from models.
- Can use models to simulate real situations.
- Can use optimization techniques in making real world decisions as well as in classroom situations.
- Can demonstrate how feedback is used to control social, political, economic, ecological, biological, mechanical, and technological systems.
- Can predict from models when a system might become unstable.
- Can communicate with machines so that he or she uses the machine effectively.
- Is familiar enough with logic circuits to understand that complex computers are made from simple circuits.
- Is willing to use the tools of technology to attempt solutions to real problems.
- Probes for causal relationships between science, technology and society.
- Questions the possible effects of technological "improvements" on the environment.
- Weighs the relative merits and risks of new products and processes.
- Recognizes the development of criteria and stating of constraints as subjective activities.
- Recognizes that technology will create entirely new possibilities for society. As a result the world will be a different place to live in the future, and that only knowledge of both technology and humanity can insure that it will be a better place to live in.

Figure 7-8. ECCP's technological literacy competencies.

There is considerable overlap between Foster & Perreault's competency list and those advanced by Rosenfeld (1988, p. 48). In writing to advise southern governors and policy makers, Rosenfeld pointed out that the needs of the future cannot be delineated with simplistic phrases such as more or fewer skills, instead the future "workplace requires qualitatively different skills and behaviors." Included among these are flexibility, increased responsiveness (time), more encompassing tasks complete with overview, troubleshooting/problem-solving and adjustments, ability to learn, willingness to learn, statistics, process control, manufacturing concepts, micro-economics, basic electronic theory, communication, readiness to take initiative.

Notably, the preceding three comprised the surprisingly small number of industry-derived sources of technological literacy competencies. The other competency lists all evolved from work done by authors in the education profession. Presented in chronological order, they include important work by: Smalley (1984), Dyrenfurth (1984), UNESCO (1985, 1984), Miller (1986), Michigan's Vocational Technical

Rank	Rating	Competency Description
1	4.51	Understand technical processes to function as a consumer, intelligent voter and decision maker
2	4.42	Communicate with technical terms both verbally and in writing
3	4.33	Know that technology has an effect on and is influenced by society, culture and values
4	4.33	Realize that technology can be destructive as well as beneficial
5	4.33	State the relationship of technology to the future
6	4.25	Identify terminology related to major field of study or interests
7	4.25	Know the design process and its use in the solution of technological problems
8	4.25	Know the strengths and limitations of current technology
9	4.25	Adapt to technological events or changes
10	4.25	Understand the processes of invention and innovation

Table 7-6. Foster & Perreault's highest ranked technological literacy competencies.

Education Service (1988), New Jersey's Commission on Technology Education (1987) and Grodzka-Borowska & Szdlowski (1989).

To enable development of an overview and synthesis of the many competency lists, the author developed a cross reference table, presented in Table 7-7 (page 164). This shows comprehensively the various competencies highlighted in the literature and their sources¹⁶. The various reports presented lists of competencies/abilities that each attributed to the technological literacy of individuals.

¹⁶Also a "Frequency of mentions" column is presented, even at the risk of misleading the reader — after all, not all mentions are equal in significance and their sum is also subject to bias due to grouping variability. For example, should a mention that results from a major national study by a national commission have equal weight with the speculative musings of an individual, perhaps poorly informed, person?

Table 7-7. Technological literacy competency overview compilation

Competency/Capability ¹	Source (see footnote at end of table)																			Freq.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1. Use both the knowledge & product of mathematics, science & technology; Apply their knowledge of principles and procedures in reaching a possible solution, or solutions; Know common theoretical aspects of the physical sciences; Apply mathematics to solve technical problems; Understanding and applying technological concepts, processes and systems	•				•	•	•		•								•			6
2. Make informed choices—both individual and societal—pertaining to technology; Make intelligent decisions regarding technological alternatives related to community or public planning; Know that technology has an effect on and is influenced by society, culture and values; Awareness of social implications of technology; Knowledge about the aspects and impacts of technology; Familiarity with technology's effects on individuals and society	•					•			•		•			•	•	•			•	8
3. Positive attitudes & values e.g., to work, personality and character; enthusiasm for work and sense of initiative	•	•		•												•		•		5
4. Creativity & innovation; Creating; Inventiveness & constructive imagination; To be inventive, and to produce original and imaginative work; Understand the processes of invention and innovation; Knowledge of human factors in innovation and invention	•		•	•	•	•	•	•						•		•		•		10
5. Technical & cognitive skills (with respect to technology & science); Describe the relationship between science and technology; Awareness of key processes and their governing principles (What is it and how does it work?); Understanding of essential relationships among key principles and areas of technology; Comprehensive of the processes by which technology functions; Comprehensive of how some of the major technologies work	•		•			•			•					•	•	•				7
6. Communication skills, including graphic communication; Communicate with technical terms both verbally and in writing; Interpret graphic communications; Writing	•					•		•								•				4
7. Observation; Aptitude for observing	•		•	•													•			4
8. Data collection	•															•				2
9. The ability to learn and adapt to changes in the workplace; Ability to react to a new situation, analyze a new situation and to decide upon the significant factors; Adapt to technological events or changes; Adjust to the changing environment; Ability to choose among technological alternatives in daily life		•		•	•	•	•		•			•								7

¹Note. In so far as reasonable, the phrasing used by the originating authors was retained. Page citations were omitted to keep the table readable.*(continued)*

Table 7-7 (continued).

Competency/Capability	Source (see footnote at end of table)																			Freq.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
10. Increased employee participation in decision-making		•																		1
11. Ability to offer constructive dissent without hindering teamwork		•																		1
12. Basic understanding and skills needed to perform entry-level jobs; Ability to apply tools, materials, processes, and technical concepts safely and efficiently; Capability of using tools, machines and materials; Ability to use technological artifacts commensurate with one's stage of development and role in life; Apply technological knowledge to a variety of human concerns and situations; Operate different devices and apparatus		•					•		•			•	•			•	•	•		8
13. Analyzing; Solve problems analytically			•			•										•				3
14. Visualizing			•																	1
15. Computing; Computation			•					•												2
16. Measuring; Aptitude for measuring; Carry out measurement operations			•	•				•					•							4
17. Predicting; State the relationship of technology to the future; Ability to project alternative futures based on technological capacities and applications; Knowledge of technology prediction; Ability to do technological futuring			•			•		•				•	•			•	•			7
18. Questioning and hypothesizing			•																	1
19. Interpreting data			•													•				2
20. Constructing models or prototypes			•																	1
21. Experimenting/research			•													•		•		3
22. Testing; Recognize the limitations of a design and to suggest modifications			•		•											•		•		3
23. Designing; Know the design process and its use in the solution of technological problems; Make designs			•		•		•					•				•		•		6
24. Modeling, Ability to use models and simulations; Make valid predictions from models; Use models to simulate real situations			•														•		•	3
25. Planning and constructing devices; Plan the process of production					•							•				•				3
26. Managing			•																	1
27. Confidence in the use of unfamiliar and possible complex equipment; Ability to conceptualize how an unfamiliar technological process or machine operates					•				•											2

(continued)

Table 7-7 (continued).

Competency/Capability	Source (see footnote at end of table)																			Freq.	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
28. Intelligence and aptitudes: Sense of space and geometrical forms				•																	1
29. Intelligence and aptitudes: Sense of mechanical functions and relations				•																	1
30. Intelligence and aptitudes: Sense of abstract relations				•																	1
31. Keep faithful and methodical records, of failures as well as of successes					•																1
32. Identify terminology related to major field of study or interests; Define technology logically in terms of components						•															1
33. Intelligence and aptitudes: Manual dexterity				•																	1
34. Means of expression: Ability to draw diagrams				•																	1
35. Means of expression: Ability with symbols and drawing conventions				•																	1
36. Means of expression: Aptitude for correct verbal expression; Speaking				•				•													2
37. Personality and character: Technological curiosity				•																	1
38. Use information about industry and technology in selecting career options and educational programs; Insight as to the relationship between careers and the technological future; Understanding effect of technology on careers; Understand the implications of technology on careers and career choice						•			•		•	•						•			5
39. Personality and character: Perseverance in research and application				•																	1
40. Personality and character: Intellectual integrity				•																	1
41. Personality and character: Desire for perfection in work; Concern for quality of manufactured and constructed products, operation of systems, and services performed				•											•						2
42. Know use of computers						•															1
43. Maintain a high degree of objectivity in assessment of technology; Understand assessment and appropriateness of technology; Evaluate technologies as to their appropriateness in our world; Ability to analyze and evaluate controversies over science and technology						•					•	•		•					•		5
44. Appreciate technological devices; Appreciation of technology; Appreciation for the products of technology and their impact on life conditions; Appreciation of agriculture and industry						•	•							•					•		4

(continued)

Table 7-7 (continued).

Competency/Capability	Source (see footnote at end of table)																			Freq.	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
45. Understand materials, processes, and their use in meeting human needs						•															1
46. Realize that control of technology involves a multifaceted systems approach with a variety of inputs; Demonstrate how feedback is used to control social, political . . . and mechanical systems						•		•										•		•	4
47. Understand technical processes to function as a consumer, intelligent voter and decision maker						•															1
48. Comprehend the relationship of our basic institutions to the technological process/progress						•															1
49. Explain how technology has and will continue to have a major influence on defining work						•															1
50. Comprehend the lineage of the technological growth of the past and future; Understanding of the development of technology and its effect on people, the environment, and culture; Connect past technological events to the present; Knowledge of history of technology; Ability to trace and analyze the historical effects of technology						•	•					•		•			•	•			6
51. Knowledge of technology (communication, construction, manufacturing, transportation); Understanding of resources, processes, outputs and their interrelationships within systems; Understanding of the concepts, habits, skills, art, instruments, institutions of a given people; Familiarity with systems							•				•			•				•			4
52. Realize that technology can be destructive as well as beneficial; Know the strengths and limitations of current technology; Perceptions of the social problems associated with technology; Knowledge of assessments of technology						•			•					•							3
53. Apply problem-solving involving human and material resources, processes and technological systems; Troubleshooting; Critical thinking/problem solving; Ability to use creative problem solving and critical thinking; Solve technological problems							•	•				•					•	•	•		6
54. Wiser consumer; Ability to evaluate a technological process or product in terms of personal benefit as a consumer; Understand, as a consumer, appropriateness and cost/benefit of technology							•		•		•	•						•			5
55. Make informed career decisions							•										•	•			3

(continued)

Table 7-7 (continued).

Competency/Capability	Source (see footnote at end of table)																			Freq.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
56. Accuracy and precision								•												1
57. Anticipating needs								•												1
58. Ethical standards/confidentiality								•												1
59. Lifelong learning/retraining; Positive attitude towards lifelong learning								•									•			2
60. Synthesis of information								•												1
61. Calibration								•												1
62. Layout								•												1
63. Listening								•												1
64. Evaluation of software								•												1
65. Keyboarding								•												1
66. Networking								•												1
67. Search & retrieval								•												1
68. File maintenance								•												1
69. Comfort with basic technological hardware (Willingness to use, and capability of using, tools, machines, and materials); Willingness to use the tools of technology to attempt solutions to real problems									•										•	2
70. Imagination to apply existing technology to new problems or situations									•											1
71. Sense of personal limits (When to call in an expert.)									•											1
72. Knowledge of technological information accessing methods and sources; Gain information									•				•							2
73. Systems thinking								•												1
74. Understand link between values and technology; recognize issues and ethics relating to technology											•			•						2
75. Understand, as a consumer, conservation; Economical use of materials/energy; Development, conservation and appropriate use of resources											•								•	2
76. Understand occupational safety; Safe work habits and skills											•								•	2
77. Read and understand technological materials; The ability to understand terms necessary for communication about technological issues												•			•					2

(continued)

Table 7-7 (continued).

Competency/Capability	Source (see footnote at end of table)																			Freq.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
78. Organize one's work													•							1
79. Apply different technologies of work													•							1
80. Carry out control operations													•							1
81. Awareness of human factors in system operation; In engineering of technological components; Some recognition of the interaction between people and technology														•	•					2
82. Awareness of quality of work life															•					1
83. Knowledge and appreciation for the utilization of appropriate technology															•					1
84. A sense of technology as an ordered and rational effort to solve definable problems																•				1
85. Some understanding of the human organism																•				1
86. Knowing which aspects of technology are changeable and which are not																•				1
87. Understanding that citizens can have some say in the control of technology																•				1
88. Know "need ==> product" process																	•			1
89. Reasoning																	•			1
90. Apply concepts of humanities, social studies, and the arts in the context of contemporary technology and recognize relationships																		•		1
91. Teamwork																			•	1
92. Use optimization techniques to make decisions																			•	1
93. Predict from models when a system might become unstable																			•	1
94. Communicate with machines																			•	1
95. Understand computers are made from simple circuits																			•	1
96. Probes for causal relationships between science, technology and society																			•	1
97. Recognize the development of criteria and the state of constraints are subjective activities																			•	1
98. Recognize that technology will create new possibilities for society and that only knowledge of both technology and the humanities can insure that it will be a better place . . .																			•	1

1-Science & technology for tomorrow's world (June 1985); 2-National Academy of Sciences (1984); 3-Halpin's (1973) doctoral investigation into the methods of inquiry of the technologies; 4-DeForge, (Ed.). (May 8, 1972). *The teaching of technology*; 5-Haimes (UK) in DeForge (1972); 6-Foster & Perreault (1986, pp. 6-7); 7-Technology education (1984); 8-NWREL (1984); 9-Dyrenfurth (1984); 10-Rosenfeld (1988, p. 48); 11-Bell et al. (1982, p. 3); 12-L. Smalley (1984); 13-Grodzka-Borowska & Szdlowski (1989, pp. 3-4); 14-Vocational-Technical Education Service (1988); 15-Miller (1986, p. 6); 16-UNESCO (Nov. 1985, pp. 9-15); 17-The Commission on Technology Education (1987, pp. 11 & 21); 18-UNESCO (Nov., 1984, pp. 3-4); 19-Engineering Concepts Curriculum Project, 1971.

Unfortunately, however, these authors were not very disciplined in describing the methodologies they used to arrive at the competencies involved in technological literacy. It would be, therefore, very difficult to replicate some of the pioneering studies. Most seemed to employ intuitive and/or individually rational reasoning (NWREL, 1984; Dyrenfurth, 1984; Grodzka-Borowska & Szdlowski, 1989). Some were consensual in nature (Deforge, 1972; the Engineering Concepts Curriculum Project, 1971; Barnes, 1987; Foster & Perreault, 1986). Several used international survey perspectives (Deforge, 1972; Barnes, 1987; Grodzka-Borowska & Szdlowski, 1989; UNESCO, 1984 & 1985). Others represented individual efforts (Halfin, 1973; Dyrenfurth, 1984; Miller, 1986; Rosenfeld, 1988; Bell et al., 1982; Smalley, 1984) and still others represented state-wide project thrusts (New York State Education Department, 1984; Michigan Vocational Technical Education Service, 1988; Commission on Technology Education, 1987).

TL: The Graphic Approach

Images often convey messages far more effectively than words. Indeed, the writer believes that if one cannot visualize a concept, one really does not understand it. For this reason, the writer sought to identify graphic representations or models of technological literacy. Several were found. They included Daiber and Wright's early work (1981) presented at the American Industrial Arts Association (AIAA) conference and shown in Figure 7-9 (page 173); McCrory's (1983) perspective, Figure 7-10 (page 172); Dyrenfurth's (1984) NCRVE-commissioned model, Figure 7-11 (page 174); and Harrison's (1988) major overview of the English perspectives on technological literacy and the education about technology, Figure 7-12 (page 175). Easily the most encompassing, and only a small part of which is depicted, the latter's work clearly needs to be infused into the consciousness of the American technology education profession. It depicts so many viewpoints and approaches to the challenges of technological literacy that it is simply beyond the scope of this chapter to even summarize.

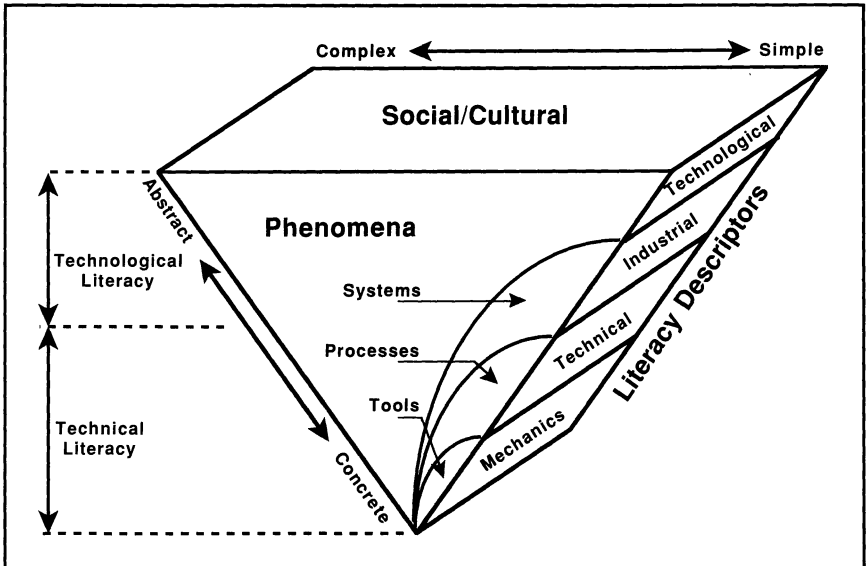


Figure 7-9. Technological literacy (Wright & Daiber, 1981).

SUMMARY

Among the important observations derived from this review was the authors' use of categories to group competencies. While certainly not all authors who approached the definition of technological literacy by establishing competency lists grouped them by categories, many did. These categories provide significant insight into the authors' view of the important generalizations (later termed vectors in this chapter) associated with technological literacy. For example, Foster and Perreault (1986, pp. 56-57) in their particularly informative and insightful *Journal of Epsilon Pi Tau* article reporting the perspectives of industrial and educational representatives, used four major categories to group characteristics of technological literacy:

- communications/computers competencies
- mathematics and science competencies
- technological systems, processes and principles competencies
- technology/society interface competencies

Earlier, Dyrenfurth (1984) used the domains of educational outcomes; cognitive, affective, psychomotor; and the components of technology; energy & power, materials & processing, communication; to

categorize his competencies. Later, 1988, he added the category of technological procedures to his list. Even earlier, Bell et al. (1982, p. 3) highlighted major areas of capability subsumed by technological literacy with the following remark: "Technology is a great driver of change and if a person is to be literate in the 20th Century, certainly some information, some understanding, and some values of technology in areas affecting American culture should be confronted and acknowledged....An analysis was made of what a technologically literate person would look like. These were then divided into four areas: **citizen, culture, consumer and careers.**"

Another approach to grouping was reported by the NWREL (1984). Their most insightful document, entitled *Technological literacy skills everybody should learn*, delineated the view of technological literacy based on employers' perspectives. In it they stated: "We suggest technological literacy is a combination of **skills and attitudes**—some very general and others very specific...:

- **Attitudes or generic skills** that can be taught in **any** class.
- **Applied skills** requiring direct instruction as well as practice under various conditions.
- **Specialized skills** that may require the expertise of someone who knows what to do and how to teach it."

Chapter Author Perspectives on Technological Literacy

Given the chapter authors' surprising tendency to converge with respect to their views of technology, this author began to allow himself to begin to feel optimistic about the possibility for a similar cohesiveness pertaining to technological literacy. Right away, however, it became obvious that this was not to be. In the first case, the yearbook chapter authors reflected the diversity, or perhaps immaturity, of the literature. Some actually defined, i.e., stated an operational definition, for technological literacy. Some instead opted to describe programs that might lead to technological literacy, while others chose to describe situations/characteristics that might be indicative of technological literacy. This necessitated treating the chapter author input in two subsections: Implications for technological literacy, and definitions of technological literacy.

<p>I</p> <p>Ability to perform in the field of study</p>	<p>Literacy as the ability to do something</p>	<p>IV</p> <p>Ability to perform with tools</p>
<p>Technology as a field of study</p>		<p>Technology as tools</p>
<p>II</p> <p>Understanding the field of study</p>	<p>Literacy as academic understanding</p>	<p>III</p> <p>Understanding how tools work</p>

Figure 7-10. Technological literacy (McCrary, May 5, 1983).

Implications for Technological Literacy

Foremost among all the implications is the assumption that one can infer what technological literacy is by looking at what technology education seeks to accomplish. This assumption is central to much of this yearbook and its validity rests on the strength of the claim that the primary goal of technology education is to develop the technological literacy of its charges. If this assumption is acceptable, then working from descriptions of technology education, we can deduce what it means to be technologically literate—but only to the extent that this goal represents the focus of technology education!

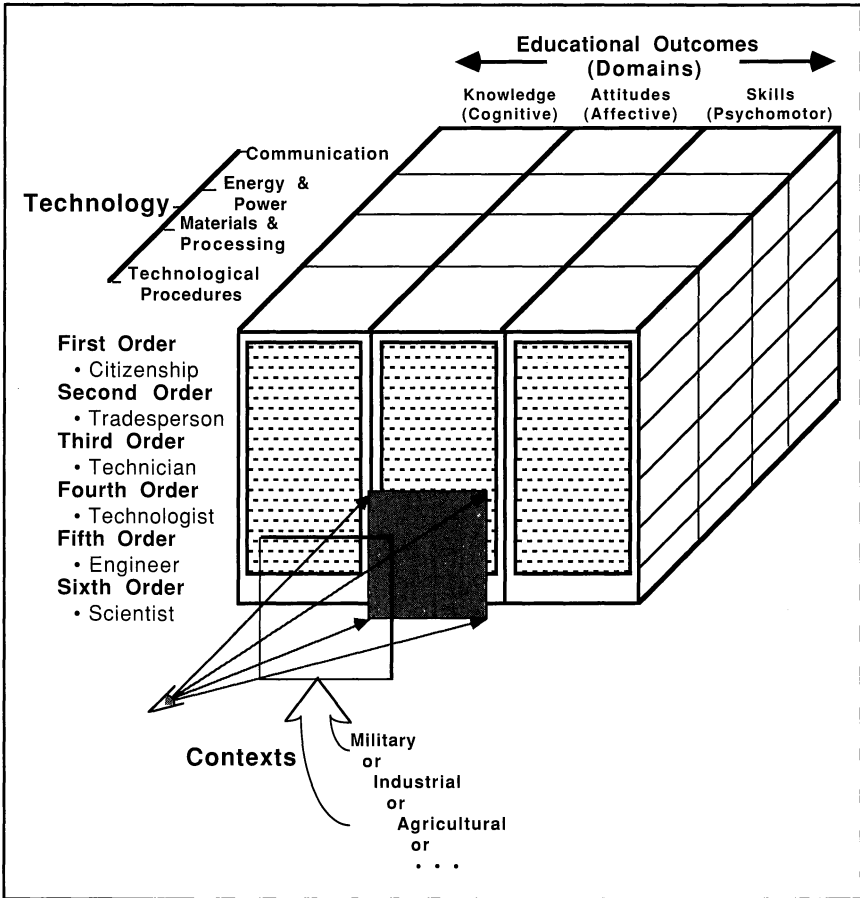


Figure 7-11. Technological literacy (Dyrenfurth, 1984).

But, even this notion of deducing a characteristic by means of the program that engenders it assumes an agreement that Todd contradicts when he points out that technological literacy is used as slogan, concept, goal and program. Nevertheless, it is clear that inherent in the words of this yearbook's chapter authors is a sense of what technological literacy is, or at least what the possession of technological literacy enables one to do or be. For example, Scarborough (Chapter 3) noted Fleming's (1987) comment that "literacy empowers one to create new,

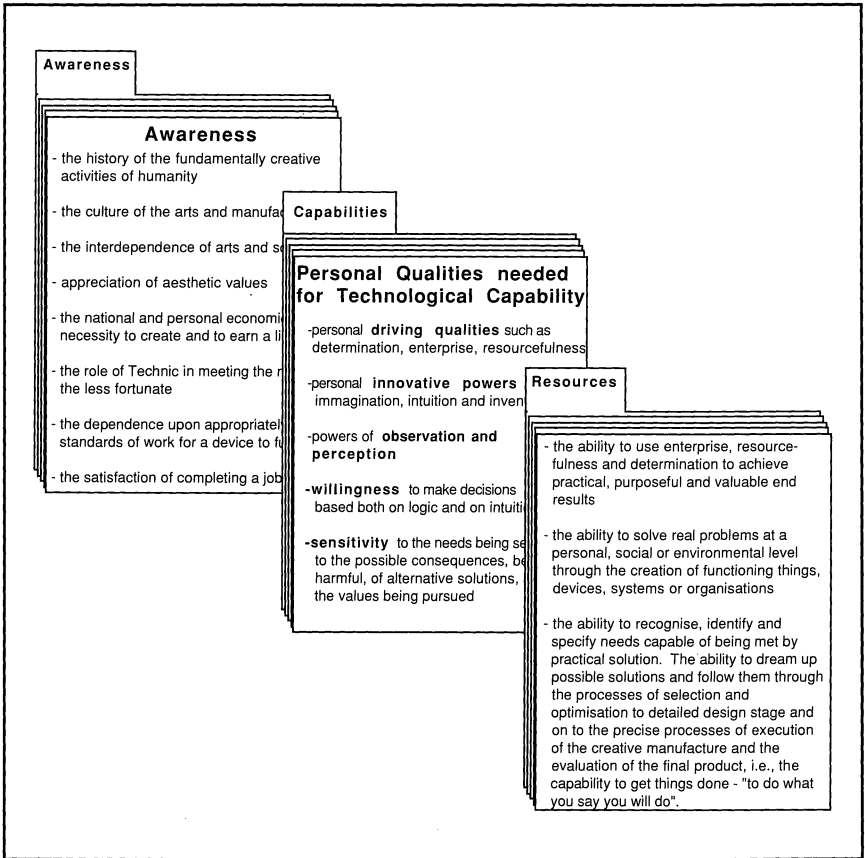


Figure 7-12. Technological literacy (Harrison et al., 1988).

more powerful cultural forms—it would follow that technological literacy enables one to create more powerful technological forms." In fact, the notion of creation, doing, or making is often noted in the literature. It often emerged (as a stress on manipulative activity) in Scarborough's comparative analysis of programs in other nations. It is inherent in Chamot's (Chapter 5) discussion of needed worker skills, and it is a central component in Barnes' (Chapter 5) assessment of what the private sector expects (key elements of tools, materials and **processes**).

Barnes (Chapter 5) additionally presents convincing evidence that the private sector is closing in on a sense of which competencies they expect the future workforce to embody. Given that they know much of their survival will be based on technological capability, these competencies provide fruitful insight as to what it means to be technologically literate. In his chapter, Barnes identified the following as technologically-related characteristics desired by the private sector, i.e., that the employee should possess and use appropriately:

- Interpersonal skills—communication
- Access, manage and control information
- Knowledge of and capability with the key elements of technology
 - tools
 - energy
 - information
 - materials
 - processes
- Problem solving
- Work ethic
- Teamwork skills
- Creativity, flexibility
- Speed
- Innovation

To the latter point, Scarborough (Chapter 3) adds information technology and mathematics and science. It is laudable that there is considerable overlap between these private sector-derived aspirations and those advocated by the International Technology Education Association (ITEA) as cited in Bensen's chapter (6):

- Understand and control industrial/technological environment
- Awareness of technology and industry
- Problem-solving
- Interests/motivate/attitudes
- Derive meaning from concrete experience
- Technical capability

Other implications for the meaning of technological literacy may be derived from Chamot's (Chapter 5) report of organized labor's desire to increase the citizenship and consumer capabilities (with respect to technology) of its members. He also noted their desire to participate in the development and deployment of technologically oriented developmental programs offered by society, employers and/or the labor organization themselves. In addition, the social activism side of technological literacy is highlighted in Todd's (Chapter 1) statement that "technological literacy is about more than education and schooling—it is also about politics and economics."

In concluding this section on the implications for technological literacy contained within the yearbook chapters, it must be noted that the existence of a manipulative component is clear to this writer, i.e., technological literacy necessarily involves at least some purposeful hands-on activity manipulating the artifacts of technology. In addition, this and all other of the implied characteristics of technological literacy are deemed to be able to be manifested at various levels of mastery, i.e., depth. Todd's, Barnes' and Chamot's work input this notion most directly but Stevens (Chapter 4) also addresses the concept of levels when he asks, "How much technological literacy is needed?"

Definitions of Technological Literacy

Readers should not interpret the preceding to suggest that the yearbook chapter authors did not include/generate actual definitions of technological literacy. Many of these were noted in their chapters. Scarborough (Chapter 3), for example said that "technological literacy was the ability to select, use and apply appropriate technology to solve problems." Bensen (Chapter 6) cited the STS 86/NAST 89 definition that "technological literacy means **understanding** the technological and scientific forces shaping our lives, and in being able to act on this understanding for our **personal welfare** and **common good**." Bensen, also cited Loepp's: "The competency to locate, sort, analyze and synthesize information that relates to achieving practical purposes through efficient action" (Loepp, 1986, p. 37) and the ACTT's (1987) definitions: Technological literacy is front end training that "spans the gap between basic skills training and machine specific training." Stevens (Chapter 4) equated technological literacy to "competence in the systematic formulation and testing of hypotheses about different ways to produce desired amenities." Although not as directly packaged as these others, Chamot's definition includes key competencies:

- Using processes not yet intuitive
- Controlling technology
- Learning subsequent skills
- Employing health/safety aspects
- Understanding of technology basics

Stevens (Chapter 4) views technological literacy as a determinant of choice and success. Bensen's list of capabilities included: Knowing the vocabulary and syntax of technology, problem-solving strategies, analyzing data and working with equipment. The capabilities highlighted in the preceding paragraphs may be considered to apply to work in the fields of manufacturing, construction, and transportation—or alternative field organizers may be used.

The implication that technological literacy exists in various levels was reinforced by the yearbook authors' direct statements in addition to being implied as pointed out in the preceding section. Todd (Chapter 1) for example, not only referred to levels of technological literacy but he also assigned a set of descriptive labels to such levels. These were, from less to more:

awareness \Rightarrow literacy \Rightarrow capability \Rightarrow creativity \Rightarrow criticism.

Stevens also spoke to levels of technological literacy when he asked, "How much technological literacy is needed?" Scarborough, despite recognizing many characteristics of technological literacy in the responses from overseas, noted that "technological literacy as a term is relatively rarely used by name." She also noted that often overseas counterparts linked, **not** equated, technological literacy to vocational education.

The conclusion of this chapter will be a section that describes a new model that integrates many of the key components/characteristics identified in this chapter's earlier sections, and one that builds on the work of the other yearbook chapter authors.

TECHNOLOGICAL LITERACY: A SYNTHESIZED DEFINITION AND MODE

Given the review of the literature plus the input of a talented team of insightful chapter authors, it remains to complete the initial task. This was, of course, to evolve a definition and model of technological literacy that synthesizes the key points in a cogent manner. One caveat is important, however! The definition and model are not presented as being the only correct ones possible, rather they should be construed as being among the many plausible ones that might be assembled from this set of inputs.

A Definition

Technological literacy is a concept used to characterize the extent to which an individual understands, and is capable of using, technology. Technological literacy is a characteristic that can be manifested along a continuum ranging from *non-discernable* to *exceptionally proficient*. As such, it necessarily involves an array of competencies, each best thought of as a vector, that include: Basic functional skills and critical thinking, constructive work habits, a set of generalized procedures for working with technology, actual technological capability, key interpersonal and teamwork skills, and the ability to learn independently.

A Model

Model construction began by distilling the key points that needed to be incorporated in the model for technological literacy. They included:

- A. Technological literacy, whatever it is, builds on a base of general education. The interface between technological literacy and general education is indistinct.
- B. Technological literacy includes as an integral core component, the mastery of a set of generalizable technological skills that focus on the process of human interaction with technology.
- C. Technological literacy necessarily includes a dimension of capability, i.e., hands-on capability, with technology. This capability may be structured into several clusters or subsystems that are valid for all of technology's application arenas. It is immaterial whether 3, 4, or 5 clusters or subsystems are used; if when taken together, they all inherently encompass technology.
- D. Technological literacy empowers individuals to progress towards goals of family, social, occupational, civic and consumer effectiveness as they interface with technology.
- E. Progress towards technological literacy is primarily fueled by three mechanisms: Systematic education, maturation, and individual effort.
- F. Technological literacy exists as a continuum that enables people to possess it at various levels that, optimally, are commensurate with their work and developmental stage.

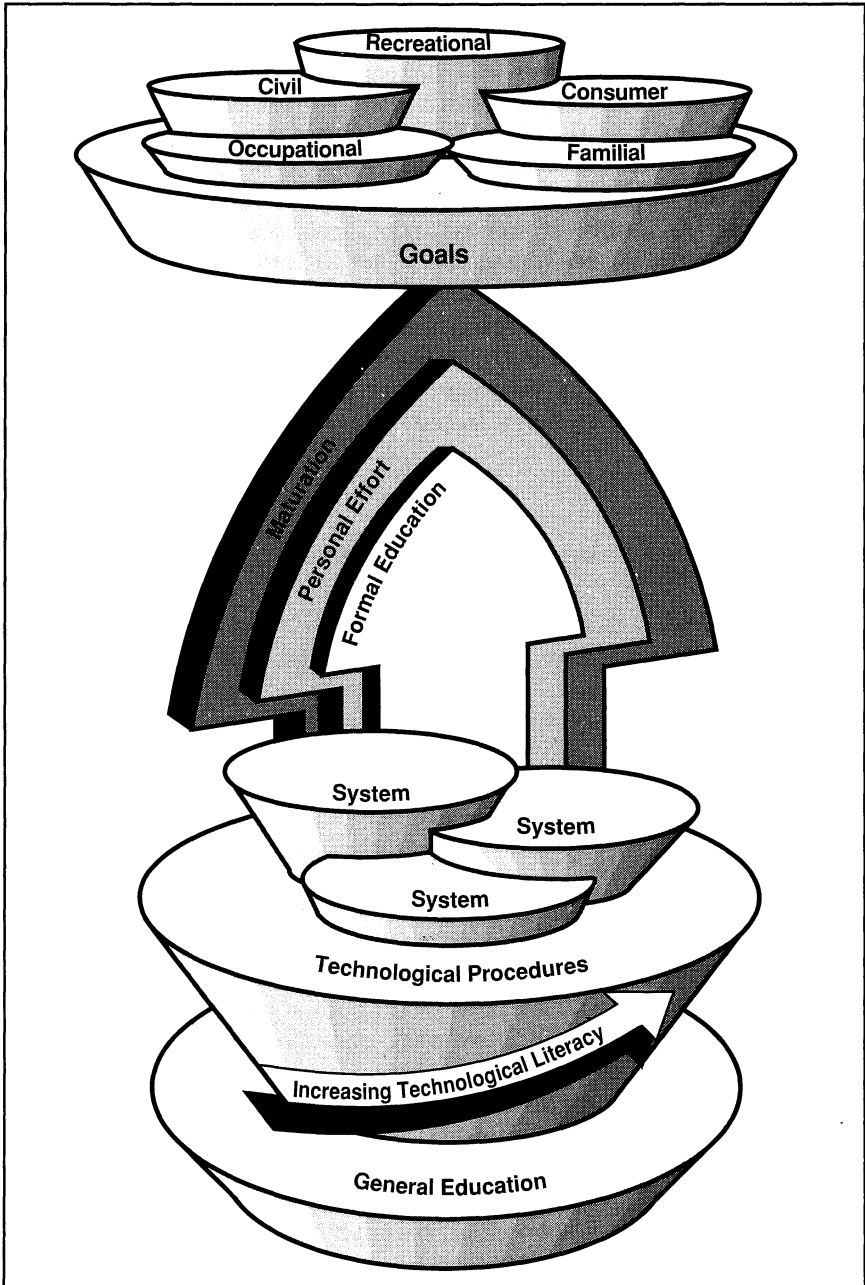


Figure 7-13. Technological literacy: A synthesized model.

Together, these six points synthesize the key input from the year-book's authors as well as the literature. Although not every point of every authority is encompassed by these generalizations, the overall intent is included. The task remaining is to produce an easily understandable model, preferable in graphic form, that succinctly communicates the generalizations. The author's attempt to create such a model is depicted in Figure 7-13 and its features are coded to identify where each of the preceding six points are incorporated.

This model builds on a large disk (A) representing the foundation established by general education. This component contains the basic functional skills, e.g., reading, writing, and calculation, that are needed to sustain all subsequent learning.

Upon the foundation established by general education, is built an ever increasing (in terms of both depth and scope) cone (B) of technologically generalizable skills, e.g., problem-solving, teamwork, interpersonal skill, and constructive work habits. These generalizable skills encompass the processes of working with technology up to the point where one transitions to competencies specific to any single technology or situation.

The generalizable skills cone (B) itself houses additional cones (C) depicting actual technological capability in the basic subsystems of technology. For purposes of this model, it is not critical what number of subsystems are used to define technology or even their exact nature. Component B, the generalizable skills of technology, is to be considered as permeating throughout each of the cones of technological capability.

The whole model seeks to represent an effort towards attainment of the human's interacting set of goals (D) depicted in the target disk.

The goals depicted by disk D are typically attained by a blend of at least three different, and sometimes complementary forces (E) consisting of personal effort, systematic education and maturation.

Finally, the overall result, i.e., the development of ever increasing levels of technological literacy, is depicted by the upwardly spiralling arrow (F) around the technological procedures (B) and technological capability (C) cones.

All components of the model, but particularly general education (A), technological procedures (B), and technological capability (C) play major roles in developing critical thinking, decision-making skills and the ability of learning to learn.

In designing this model, the attempt was to use graphic implications to descriptively reinforce key characteristics of the concept of technological literacy. For example, cones are used to represent the increase in both breadth (scope) and depth that can result from enlightened effort over time. Similarly, an upward spiral is used to depict technological literacy's levels because of a spiral's never-ending characteristic as well as its use as a metaphor for the systematic reinforcement and enhancement of previously learned capabilities. The parallel to the spiral curriculum advocated by Brunner and others is deliberate.

The cones representing technological capability are deliberately shown as intersecting to represent the interaction among technology's sub-systems. Similarly, the goals for which one seeks to develop technological literacy are depicted as interlinked. Also the entire technological domain of the model (components B & C) is shown truncated at its base to suggest that it begins somewhere within general education.

Another intent is to emphasize the dynamism of this model. For this reason, goal oriented arrows are used to depict human effort/action along with the spiral. In fact, the author also envisions the depicted components of technological literacy to be competency vectors that have both a direction and a magnitude and that these can change in direction and dimension as well as in composition. Given the ever evolving nature of technology; it was mandatory that a technological literacy model be capable of accommodating change.

To summarize, this model demonstrates that—in today's and tomorrow's ever more complex and technological world—technological literacy is a key element to achieving efficiency in personal (familial), social, civic and also occupational spheres of activity. By mustering the forces of personal effort, maturation and systematic education: technological literacy is achieved by mastering the key essentials of the ways of interacting with technology (technological procedures) and technology's core capabilities within each of the primary subsystems of technology (e.g., energy & power, materials & processing, and communication). All of these, of course, build on a solid base of general education (basic functional skills). Teamwork, constructive work habits and critical thinking skills are reinforced by their technological applications. The synthesis of these capabilities results in increased

capacity for "learning-to-learn". Then, as people advance, and as depicted by the model's upwardly spiraling ribbon, the requirements for technological literacy escalate as people assume positions with ever increasing responsibility.

In this manner, the proposed model incorporates seven key competency vectors which detail the specific nature of technological literacy that will be central to the success of humankind's future. Extracted from the model, they are:

- 1. Teamwork & interpersonal skills/collaboration**
- 2. Constructive work habits/values**
- 3. Technological procedures**
- 4. Technological capability**
- 5. Basic functional skills**
- 6. Thinking & decision-making skills**
- 7. Ability to learn/adaptability/learning to learn**

Intent

This model was developed for the consumption of the profession and is dedicated to it. Note that it is intended to be representative not absolute; to be provocative rather than silencing; and to be used rather than ignored. The model also represents the culmination to date of the author's pursuit of the concept of technological literacy. His interest in technology, and indeed the bulk of his understanding of it, are directly attributable to the vision and genius of Henry R. Ziel¹⁷. It is to his memory, and to all who join him in the quest of helping develop the technological literacy of current and future generations, that this chapter is dedicated.

¹⁷Dr. Henry R. Ziel was Professor and Head of the Department of Industrial and Vocational Education, University of Alberta, Edmonton, Alberta, Canada.

SECTION III

TECHNOLOGICAL LITERACY: IMPLICATIONS FOR PRACTICE

This yearbook's last section focuses on the implications of technological literacy, via its models, for the practice of the profession. Technological literacy, the principal outcome of technology education, should serve as the focal point of practice for the profession—i.e., the venue where practitioners encounter students.

The central goal of technology education as a subject in the public schools is to develop the technological literacy of young people. People need technological literacy to function fully as citizens in today's world. It is evident that young people in grades K-12 need instructional programs that will help develop their understanding of, and capability with, technology. Technology education is the logical and primary vehicle through which the development of technological literacy can be accomplished.

But how is this done? Chapter Eight synthesizes key practitioner perspectives about the practice of education about technology. Implementations in the elementary, middle, and senior high schools are individually described. The perspectives of exemplary practitioners—Terry Thode, Les Litherland, and Robert Daiber—represent an intriguing set of successful approaches for elementary, middle, and senior high schools respectively. The enthusiasm for, and interest in, technology that elementary students carry home to parents speaks eloquently to its value as an integrator and as an essential part of the regular elementary classroom experience. Middle school students learn to live with their surroundings and the influences that come with their ever-enlarging environment. At the high school, technological literacy is a broad outcome that involves advancing coherent cognitive, psychomotor and affective development of students. As such, this chapter examines the goals of technological literacy as an outcome of education about technology in the context of K-12 human growth and development as well as according to the curricular goals of such schooling.

To implement technological literacy is somewhat analogous to the lives of our country's pioneers. In order to survive, settle, and thrive,

these individuals needed support, supplies and protection. Technology education instructors too, need support to **survive** in their schools, let alone to flourish by enhancing their programs. In Chapter Nine, using a case study, Roger Stacy addresses the role of the state supervisor in providing such support and then even extending it to leadership. Similarly, Harry Tobin, in the role of a local supervisor, highlights activities that help professionals challenged by rapidly evolving technology, system policies, and demanding students. Both leaders call for supervision with greater fervor to develop an even greater, more pervasive understanding of what technology is all about and what technology education should be.

Chapter Ten explores the implications of technological literacy for the practice of teacher education. The authors, each from leading technology teacher education institutions, examine the necessary consequences of technological literacy for the preparation of instructors. To enable the addressing of technological literacy in the public schools, and to do so for all youth, a supply of capable teachers must be assured. It is the institutions that must meet the challenge of recruiting and developing such sorely needed instructors. The educational system seems negligent in not providing students with a basic appreciation of the risks and benefits of their technological culture, let alone a capability with technology. Technology education majors must be empowered to develop such competencies and inclinations. Unfortunately, the topic of technological literacy has been used rather casually by the profession for several years, particularly in teacher education. Larry Hatch and Ronald Jones, however, share a perspective and a framework of knowledge domains and components that will foster success.

Finally, the eleventh and last chapter most fittingly is developed by Paul DeVore. It is at once an end (to this yearbook) and a beginning for our profession. He presents us with a vision of a future so compelling that it will serve as a beacon for years. DeVore crafts this vision carefully by first reviewing the contributions of curriculum models and noting the absence of a pervasive theory base. He then walks the reader through a progression of futures including crisis scenarios caused by the inappropriate use of technology. Hope is fanned by a predicted shift in values and a significantly increased role for philosophy as a guiding force—a philosophy that incorporates technology.

In answering the question of "What knowledge is of most worth?" DeVore responds that, given the nature of technological literacy, it

must include three ever-present pillars: Technology and Progress, Technology and the Environment, and Technology and Ethics. This leads DeVore to optimistically envision a major paradigm shift leading to an entirely new grounding for technology education. The gauntlet is thus nobly cast—we only have to pick it up and to live the dream!

CHAPTER EIGHT

IMPLEMENTATION OF SCHOOL-BASED TECHNOLOGY EDUCATION PROGRAMS

by

Robert Daiber¹

Les Litherland²

Terry Thode³

The central goal of technology education as a subject area in public schools is to provide young people with technological literacy. In this decade, much discussion has occurred among educators with respect to the nature of the concept and the methods by which technological literacy is to be developed. During the discussion, a surprising degree of uncertainty regarding technological literacy has been revealed. Wright (1980), Miller (1986), Dyrenfurth (1987), Maley (1987), among many others, have published their perceptions of technological literacy in an attempt to help practitioners in public schools begin to consider the implications technological literacy has on instructional content and the school curricula. Fortunately, as is evidenced by this yearbook's preceding chapters, we are beginning to see some convergence.

The primary significance of technological literacy is that it represents a critically needed action for this era. As indicated by the National Science Foundation report, *Educating Americans for the 21st Century* (1983), technological literacy is a basic capability that all people need to possess. Maley (1987) reinforces this by identifying five functions citizens perform which are dependent upon technological literacy:

- a user of a vast array of technology,
- a decision maker—both personal and as a citizen regarding technology,

¹Robert Daiber, teaches technology education at Triad High School in St. Jacob, Illinois.

²Les Litherland, a Crista McAuliffe Teacher for 1988, taught technology education at Everett Junior High School Colorado, and now is an independent consultant.

³Terry Thode is an elementary school teacher at the Hemingway Elementary School, in Blaine County, Idaho.

- a purchaser and consumer of a wide variety of technology,
- a key element in the further use and development of technology,
- a worker and wage earner in an increasingly technological workplace. (p. 46)

If technological literacy is an outcome that schools are expected to foster, then it is evident that young people in grades K-12 need instructional programs that will help develop their technological literacy. The fashioning of systematic instruction to foster technological literacy represents an enormous educational challenge for the 1990's. To be practical, as well as sensitive to varying reader interests, the authors approached public school practice by describing technology education programs at each level of schooling. Because of the premium placed on "slices" of student time, for the most part, the approaches described involved the revision of existing industrial arts programs to become technology courses.

This chapter's sections⁴ describe the perspectives of exemplary practitioners of technology education in each of the levels (elementary, middle/junior high and senior high) of public schooling. It should be noted that the writers are not presenting "the only way to implement technology education," rather they are sharing insights that have helped make them and their programs exemplary.

TECHNOLOGY EDUCATION IN THE ELEMENTARY SCHOOL

Given that the characteristics of human development, attitudes and impressions form early, if society wants technologically curious and capable high school graduates, it is imperative to begin "forming the clay" early. What was once termed a "need" to teach about technology has changed to a "must" today. Preparing today's students—particularly elementary students—to be competitive and informed citizens in a technology-based society is a key concern to all educators. The future success of our students in the job market or in higher education is directly related to their ability to adapt to change, to solve problems, to apply their science and math knowledge—in short, to understand and use technology.

For elementary educators, this means providing the proper learning experiences that integrate technology, complete with hands-on

⁴Eds. Note

experiences, into the classroom. Students must learn from technology, about technology, and with technology whenever appropriate. Developing an awareness of technology's effects on our environment today, as well as predicting the future changes technology will bring, are important concepts to explore. The time to start the exploration is at the elementary level. Elementary students have an innate curiosity about their surroundings and most often they are virtually fearless when it comes to trying out new ideas and technologies.

Effective Technology Education for Elementary Schools

At the elementary school level, technology education needs to be integrated with other subject areas to be most effective. Technology infuses readily into the regular classroom curriculum, whether it be language arts, science, math, reading or geography. However, one major problem currently slowing the implementation of technology education in the elementary school is the classroom teachers' apprehension of the unknown. After all, how can teachers be encouraged to incorporate technology into their daily lessons when they have not been prepared to do so? Furthermore, the image of technology can appear to be intimidating—particularly when one does not possess an overview of it.

But, this need not be as big an obstacle as it might appear. What is exciting about teaching technology is that teachers can learn along with the students, and often can learn from the students. Learning becomes exciting to both teacher and student when technology is holistically applied to the many other activities happening in the classroom and outside. The emphasis is placed on increased problem-solving, hands-on exploration of current technologies and the exploration of new technologies—then subsequently sharing that information.

To be effective, educators also need to address how and which competencies the elementary schools are to teach. Then technology's relationship to these can be explored. In some cases technology could be the object of instruction and in others it can become the vehicle used to achieve other competencies. Since there is such a rapidly growing knowledge base, students (especially at the elementary level) should be exposed to "need to know" information rather than "nice to know" trivialities. There is little reason why students should memorize all the facts in every subject. Learning where to locate current information on a topic, learning how to access it, and then being able to evaluate its use, appear to be more important skills for the student—now and even more so in our information-swollen future.

"Real" Technology or Simulation and Models

It is also extremely important to allow students an opportunity to explore the actual technologies rather than just models or simulations. At the elementary school level, "real" technology often is limited just to computers. While at least this is a step in the right direction, there are many other technologies that play an important role in business, industry and life. Students need to be aware of how a laser works, what fiber optics are, how robotic sensors work, what a modem is, how to produce graphic images and the like. While often "real" technology equipment is not available at an elementary school, it usually can be borrowed, to provide hands-on experience. Reliable sources include a junior or senior high school technology or science department. Many times, however, it is surprising just how much of such equipment is actually available, right in the elementary school, to an imaginative and assertive teacher.

The formal funding of a technology program in the elementary school can be difficult unless it is included in the regular curricula budgets. Computers and computer labs are no longer uncommon at the elementary level but the need for other technological equipment seems less apparent. In some school districts, parents and community members have rallied to support elementary technology programs and equipment. More formally, grant money for elementary technology programs has not been readily available. However, the current emphasis on upgrading students to be more competitive in the world market has started to make available some special funding opportunities, especially for science- and technology-related programs. Elementary teachers should not be reticent to apply for funds conventionally targeted for middle/senior high schools, because they can make a good case using a "model program" and "foundation building" rationale.

Problem-Solving Strategies: Key to Technology Education

Technology has always been important to our lives. Technology educators believe that in order to use it to humankind's best advantage, today's elementary students must be prepared to make informed decisions about technology, its uses and its further development. Many agree that this requires students to capably employ a variety of problem-solving strategies.

The term "problem solving" has become popular in today's education worlds. It has become a major emphasis in science and math curricula.

It is therefore important to distinguish true problem solving from tasks that mainly require students to follow directions. Problem solving in the true sense will cause students to make decisions throughout every step of the process—in other words, to THINK! Such a process also provides constant feedback to make corrections and adapt to new information. An example of a student-generated strategy for problem solving is shown in Figure 8-1. The students selected the word SEARCH as an acrostic to help them key into the strategy steps.

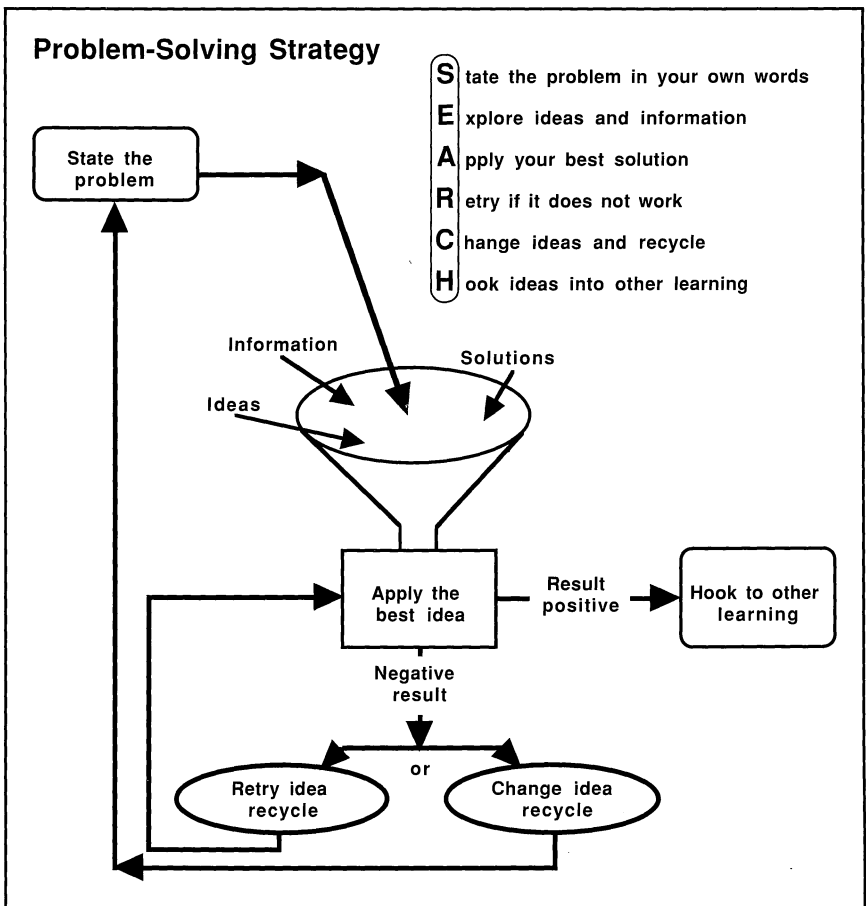


Figure 8-1. A student-generated plan for problem solving using the acrostic SEARCH.

Students should develop problem-solving skills that enable them to identify and then think through a problem, whether it be in reading, math, science, or some personal area; to select a solution; to try it; and then evaluate the outcome. If necessary, students may need to recycle that solution through the problem-solving steps again, or they may choose to try another solution. In the elementary school, it is important to begin with an activity where the goal or task presented to the student is clear. But, the problem needs to be open enough that students need to make key decisions. Although parameters should be provided, it is important not to give step-by-step directions. Elementary students should be challenged to think and make their own decisions! It is never too early to begin this.

Furthermore, it is essential to extend problem solving to higher levels of the cognitive domain's thinking and/or critical thinking skills. Analysis, synthesis, and evaluation are skills often associated with gifted programs in elementary schools, but in actuality all students benefit from learning how to implement them. Similarly, the characteristics of relatedness is an important curriculum design feature in the elementary school. Because of the students' early stage in terms of their range of perspective; new ideas, skills, and attitudes must be anchored to what they already know. If an idea or solution cannot be linked to other learning through analysis or synthesis, it will probably not be very useful to the student, either now or later.

Articulating the elementary school's technology education curriculum with middle school and high school technology education offerings is equally important. As depicted in Figure 8-2, the exploration during elementary years allows students to be advocates of technology at the junior high or middle school. They are able to focus on more advanced topics because of their elementary experience. Other programs such as Advanced Technology or Principles of Technology also utilize and reinforce the knowledge students have gained in elementary technology education. Furthermore, the process of developing the desired articulation invariably brings technology educators from elementary, middle and high schools together. This leads to a useful exchange of ideas, resources, and support that benefits all involved.

Elementary School Technology Education in Action

Recognition and implementation of a guiding set of principles is central to quality elementary school technology education. The following

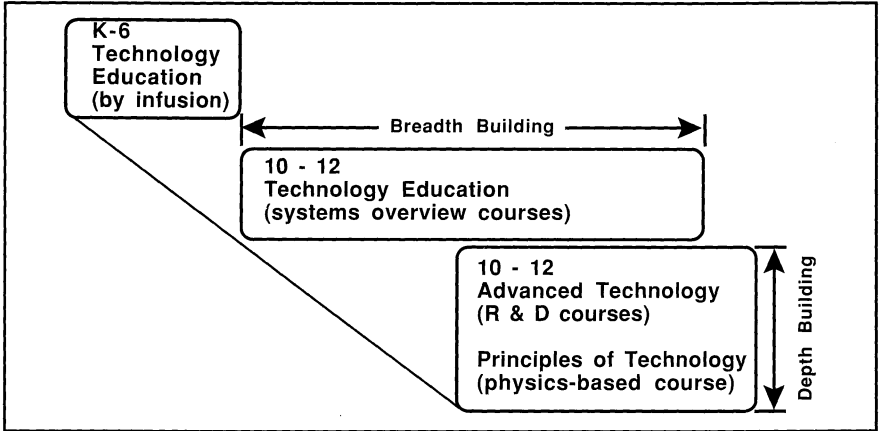


Figure 8-2. The K-6 elementary technology program is expanded in the junior- and high school levels.

are among the most important. Elementary school technology education programs should have students actively involved with technology using a hands-on approach. The curriculum must cover the fashionable current technologies as well as basic technologies and the emerging technologies. Because of the very nature of technology and the elementary school program, the technology curriculum needs to be flexible and adaptable to changes. The realization that curriculum must be continually updated and periodically re-evaluated helps keep teacher enthusiasm and involvement at a high level. Incorporation of these principles is challenging but absolutely necessary to assure quality.

While teacher-directed activities are necessary to initiate technology activities at the elementary school level, the majority of classroom time should be dedicated to student-centered, hands-on, exploration time. For example, in the technology education program in Idaho's Blaine County, elementary students follow a curriculum that centers around six modules: problem solving, computer applications, robotics and automation, light/laser applications, communications, and future technologies. The use of high technology equipment such as computers, robotics, photography, communications, electronics, and lasers are stressed in their problem-solving activities. Each module contains instructional goals, objectives and suggested activities for the students. The objectives for each goal are specific, but they allow students to use problem-solving skills in selecting the appropriate technology tool or

solution to follow. Every student completes an introductory activity in the proper use and care of each piece of equipment. Students quickly grasp the idea that new technologies present different safety requirements and that the effects on life and the environment depend on careful use and critical assessment of each technology. Each module is briefly described to give an idea of what is happening in elementary technology education today.

Problem solving

Problem-solving skills are introduced first since the ability to "think" is essential throughout other technology areas. A sample performance objective for a typical problem-solving activity for elementary students is to design and build, using straws, the tallest free-standing structure that will support the weight of a tennis ball. Students must make decisions on, among others, how to connect the straws, where to place the tennis ball, and the best design for strength. Because of elementary students' need for closure, it is important that all activities include a summation or evaluation process. This activity infuses preliminary concepts from physics, materials testing and strength, structural design, as well as different material fasteners into a fun event. Obviously other problem-solving activities could be incorporated into each technology when it is introduced and each provides additional opportunities for the infusion and reinforcement of key concepts from other disciplines.

Computer Applications

Computer technology has already been introduced to most elementary students. In technology education, it is therefore important to make certain the students understand the computer is a tool, much like a hammer, that has special uses rather than just to play games. Learning when to use the computer for a specific task is a must. Students also should become acquainted with as many different computer systems as possible.

Elementary school students may be introduced to problem-solving software, graphics applications, keyboarding, LOGO, and word processing in the early grades. Upper grade students may design and use a database to organize and retrieve data, use a spreadsheet application, access information via modem, digitize pictures, and produce a CAD original on a plotter or printer. Students may also become deeply involved in desktop publishing of school newspapers and yearbooks.

Robotics and Automation

Sometimes true robots are beyond the budget of an elementary school. Here is a situation where a robotic model or simulator is quite appropriate—fourth, fifth, and sixth graders can design and construct syringe robotic models and explore hydraulics or pneumatics as well. Others may elect to assemble model robotic kits or learn how to interface a computer with a robot. A sample performance objective in this area is to plan, design and construct a simulated robotic arm that has mobility in two directions and that can grab and move an object from one location to another. Students are involved, using problem solving, in determining materials and fasteners, designing actuators and grippers, etc. to best meet the objective. They also make decisions whether to use fluid, mechanical or some other power system to move the robotic arm.

Lasers

Students may be required to research and report on different kinds of lasers and how lasers are used in our society. After exploring the properties of light such as reflection and refraction, students learn how to send voice transmissions over a fiber-optic cable. Students in grades K-3 may produce lasergraphs as a beginning darkroom experience. Older students may construct alarm systems or measurement devices that utilize the laser.

Communications Technology

Communication is one area that easily integrates with the regular classroom curricula. Using readily available technologies, students may produce a professional-appearing written report or a video presentation complete with music and sound effects. Communication technologies allow students the opportunity to try different presentation techniques besides the traditional paper and pencil ones.

In photography, the students may experiment with sunprints and pinhole cameras as a prerequisite to actual black and white photography. Older students may roll their own film, develop it and make prints. These students are also responsible for the production of the school yearbook from the photography, to layout, occasionally even the printing process, and finally the collating and binding process.

One activity which all students enjoy is the creation of a sound/video recording to illustrate a technology-related concept or to enhance an

activity in another subject area. Often they use an electronic keyboard and animation techniques from the computer to create the desired effects. Often students form teams for taping programs requested by other teachers. This is an excellent time to bring in the ethics involved in copyrights.

To properly reflect our electro-mechanical world, teachers need to incorporate experiences that reveal this sector's mysteries. For example, in electronics, the students may experiment with circuitry as well as learn how to solder robotic and electronic kits. Always a student favorite, to learn about the components in today's machines, is a "machine dissection," i.e., disassembly activity. The parts are then salvaged to be used in other activities such as a "Rube Goldberg" project.

Learning about communication satellites in the Clarke Belt ties in well with geography lessons. Students are excited to learn what the footprint of a satellite is and how to locate it on a continent or country map. This provides a unique way to study latitude and longitude readings. Students learn how to locate a certain satellite and assist in relaying its signals to other systems.

The modem is another important tool to introduce to students. Using it, they can access a commercial database to aid in researching current information or use the modem to send or receive electronic mail from other schools. It helps students understand how quickly we can access information from anywhere.

Future Technologies

Elementary students are eager to learn about exciting new technological developments. Exploration of space and aerodynamic concepts lead students in predicting what else might be possible. Using concepts from superconductivity research and basic genetic engineering, they can explore the possibilities of the future. They can also analyze and evaluate the new technologies' impact on their community and the world, today and in the future. It is important to note that instructors and students will often be learning the material related to these emerging technologies at the same time. Joint problem solving by sharing information and resources is a key concept to the technology education movement, particularly at the elementary school level. Instructors must not view themselves as the "sole source" for information.

The Goal of Elementary School Technology Education

There are many activities available for use in an elementary school technology curriculum that allow students to learn about technology and how it fits, or doesn't fit, into both their and the larger world. All can be exciting and all can be legitimately used to reinforce the multiplicity of learning goals imposed on the elementary schools. Technology education gives elementary students an opportunity to learn about new technologies and to become aware of their applications in the real world. Students gain more tools to choose from and more problem-solving strategies to enhance their initial thinking abilities. Students are helped to apply what they have learned about technology and relate it to other subject areas. Technology education is "fun" because it is relevant, and best of all, it is a hands-on learning experience yielding genuine understanding.

Where Next?

The success of the Blaine County Elementary Technology Education program is credited to the combined efforts of the school board, the parents, the community, the administrators, many cooperating teachers and, of course, the students. In other schools, both those long involved with elementary technology programs and those just starting, instructors are finding out how excited students are about technology and its uses. The enthusiasm for, and interest in, technology education that elementary students carry home to parents speaks forcibly to its value as an integrator and as an essential part of the regular elementary classroom experience. However, enthusiasm alone is not enough to spur the growth of elementary technology education programs in the public schools. More efforts must be directed toward providing funding sources for the implementation of elementary technology programs, and for teacher inservice activity in technology and problem solving. And, most importantly, the existing resource network that provides support and updated information to those programs already in action must be expanded!

TECHNOLOGY EDUCATION IN THE MIDDLE SCHOOL / JUNIOR HIGH SCHOOL

Middle school—this is the critical time during which students start to reach out to better understand the world in which they live. Technology educators are charged with helping students develop a foundation with which to learn to live with their surroundings and the influences that come along with their environment. Central to this is the characteristic, technological literacy, that serves as the focus of this yearbook.

The real challenge at hand is how to implement activities that develop technological literacy in students. But, before the actual methodologies involved are shared, an explanation of the foundations for decisions as to what subject matter should be included in the offerings to the students is in order. The following competencies represent what all students must have to survive or cope in the technological future. Students should be able to:

- evaluate and analyze,
- solve problems,
- think critically,
- make decisions when information is incomplete, and
- apply abilities to new areas.

Before any changes are made in the existing middle school curriculum, an assessment of the entry level of students, with respect to the competencies highlighted in the preceding paragraph, should be made. What do they need? And what do they already know? (with respect to life in a technology-intensive future). The intent was to evolve a dynamic curriculum, that is, one that can be changed with the times to better assist the students to meet their needs.

Much of the content of any curriculum should be based on the individual education needs of the students, viewed, of course, within the perspective of a technological society. To make changes merely for the sake of change is wrong. But, to change to help students is not only right but is ethically mandatory.

The main emphasis in this section will be to describe those portions of a middle school technology program that are designed to make direct contributions to the technological literacy of students. The focus will be on grades 7 and 8. At these levels, a typical school may offer courses in technology education, such as:

- Introduction to Technology
- Exploring Technology
- Year 2050

The Critically Important First Course

Built into the first course is a set of activities called “media reviews,” that are used to review what is known. The first few minutes of each period are dedicated to discuss articles or reports the students bring in. These items usually are very timely, typically they are extracted from a daily newspaper, and quite often they require more time to review (properly) than the few opening minutes of the class period allow. But this is actually advantageous because such articles often relate directly to the period’s or week’s goals and therefore can be integrated into the ongoing activities. The main point is, that instructors must be very flexible (and quick) to take advantage of students’ interests and relate them to the planned activities, e.g., a lift-off of the space shuttle. One could spin-off this event and have discussions, watch the lift-off on a satellite TV monitor, and then discuss new ideas for using the shuttle to help with key area or societal problems.

The introductory course need not necessarily impose any particular direction for the technological articles that are to be brought in—as long as they generally address technology. Anything the students feel is important enough to be brought in should be discussed. The discussion can be directed to the program’s offerings, and should be carefully controlled to eliminate time wastage. By the end of the introduction course (Grade 7), each student should be able to recognize different technological advancements and their impacts on his/her life. If successful, the first course should have heightened student interest in technology.

Expanding on the Start

The eighth grade could offer students the opportunity to take either the Exploring Technology course, or the Year 2050 study of the future. During these offerings, the media review component of the course is used differently in that the instructor provides more guidance to relate the articles/vignettes more directly to the studies at hand. For example, an exploring technology course can be designed to address four main systems of technology:

- Communication
- Construction
- Manufacturing
- Transportation

Therefore, the media review activity would best be restricted to the area being studied at that time. Although such limitations are imposed, overall the activity is still quite open, for discussions may include applications in any of the four systems. For example, the space shuttle is mainly used for transportation, but NASA spin-offs relate to all areas. The understanding of the source and distribution of tax money spent on the space program alone is a major understanding for the students to grasp.

The Year 2050

When the students go into the Year 2050 course, the media review activity is strictly limited, for now they are studying the systems within each of the four areas. Since this course is future-focussed, the media review is required of each student so they develop a data base from which to predict the future. Also, if the media reports show where the interest of individual students lie, the instructor must be poised to take advantage of this.

The media report activity results in the direct involvement of students with research by reading the daily newspapers, reviewing magazines, and scouring the library. Additionally the instructor's input relates student learning to what is being offered in the course. Because a large portion of the course information is student-generated, their ownership of it makes the rest of the activities easier to implement.

Maintaining the Focus on Activities

There are also many other activities that address the goals of each course offering in a technology education program. For example, in the exploratory seventh grade program, the main emphasis is put on the decision-making phases of the desired processes. Extensive brainstorming activities are used to develop skills in problem solving. When working with the communication activities, the complete system is presented, so the students have a basis from which to begin their study of the area. In manufacturing, the overview traces activities from the conception of a product through to the selling of the finished item to the public.

In the eighth grade exploratory course, weekly assignments are used to expose the students to a particular system. During that week everything worked on pertains to the chosen system, such as transportation. The activities work best if tied to a region and/or time, such as a styro-foam glider or airport closure due to snow, if it was reported in the media that day. When the cross-country photovoltaic vehicle teams took their cars across Australia, solar cell-powered cars were made and raced in class.

After all the systems have been studied, a two week period is used for activities that integrate all the parts. In summary, the attempt is to have activities that relate to the media reviews as much as possible. This reinforces the "living curriculum" concept and maintains flexibility. Admittedly, this approach is certainly demanding of the instructor, but the results are well worth the effort.

Whatever activity one chooses to assign students, it must of course be tied to the previously established technology education program goals. The key question is: Does the activity help meet the established goals in a significant way? If not, then eliminate it from the program even if it is "neat." Assuming systematically developed program goals, activities that do not contribute directly to them, and/or that do not have a bearing on the students' future are time consuming and logically worthless.

But, what if two courses are not sufficient to meet student demand? During the last semester in the Eighth Grade, an opportunity can be offered to those who wish to learn even more about the technological world. This course is called the Year 2050 and it concentrates on the future. Simply described, the students select a major technological area, i.e., one of the four systems, and then study the present state of that area. After building a data base, each student selects a minor concentration within that area, such as automobiles in the transportation system. Students project the established information into what they think the future will hold. To incorporate the vitally needed hands-on component, the students also design a prototype of their choice (related to the problem they explored) and build a scale model of the design—preferably a working model.

Upon completion of the plans and the model, students present, to the rest of the class, and/or an industrial representative, their concepts of the future. They also defend the design of their prototype. This activity enables class members to assess critically the thoughts of the presenter and his/her design rationale. It also gives the students an

opportunity to develop their communication skills and the process exposes all classmates to other portions of the systems being studied.

In conclusion, the curriculum design principle to be stressed is that all activities must be related to the student needs and to their future. Although the latter cannot be known with certainty, it must be addressed through a conscious assessment of the probabilities. Teachers must guard against succumbing to desires for comfort. Too many times, projects or activities used in our laboratories are chosen to be easy for the instructor or they are drawn from his/her background and/or interests. Care must be taken when selecting activities to be used—students and parents can readily recognize what is needed and what is not. To keep students in the program, and to keep the program in the curriculum, technology education must offer what is important to the future and what builds technological literacy as the basis for future action.

TECHNOLOGY EDUCATION IN THE SENIOR HIGH SCHOOL

The goal of developing technological literacy through senior high school offerings provides schools with valuable opportunities. Besides their own intrinsic value, technological literacy competencies also reinforce other important outcomes. The technological literacy students acquire in high school will be evidenced by their mastery of technological language and communication, decision-making and problem-solving abilities, and by their technical skill. Some educators have confused technological literacy in high school with computer literacy. This misconception of technological literacy has led some schools to offer (mistakenly) computer literacy courses while really intending to develop a more technologically literate student. As indicated by Boyer (1983) among others, computer literacy is not synonymous with technological literacy: "The great urgency is not computer literacy but technological literacy, the need for students to see how society is being reshaped by our inventions, just as the tools of earlier eras changed the course of history." (p. 111)

The 1988 Technology Education Advisory Council report, *Technology: A National Imperative*, characterizes technology education as a contemporary subject that addresses many aspects of learning which contribute to the development of technological literacy. These

aspects include the use and control of technology, the development of technology and its effect on people, the environment and society.

One of the key tenets of technology education is that the subject seeks to develop a social and technical awareness in students. Such an awareness is necessary for students to truly understand technology and its impact on society and the world. High school is often marked by frequent student questioning of authority. It is important that high school students channel some of this attitude into technological arenas. Students must learn to question technology, not merely to accept it as "fait accompli."

However, some educators view high school technology education much more narrowly. They see this subject as providing technical skill development for students' occupational and avocational pursuits. Technical skill development, while not synonymous with technological literacy, is certainly a part of the concept.

Growth and Development for Technological Literacy

Technological literacy represents a broad learning outcome of the high school curriculum because it involves the coherent cognitive, psychomotor, and affective development of students. Each domain of learning must be addressed if technological literacy is to be achieved. Furthermore, to be a legitimate user of student time, technology education must raise the level of technological literacy as well as broaden its scope. The following explanations relate each domain of learning to the development of technological literacy.

Cognitive Development

As children grow and develop, they acquire the ability to perceive, think, and reason. These abilities describe the cognitive domain of learning. Each of these cognitive abilities is important to the development of technological literacy because all are necessary for students to comprehend the meaning of technology and to engage in problem solving.

Language development will always be a highly important part of technological literacy because new terms are evolving constantly from technical developments. The following represent just a few that have become a common part of our language in the 1980's: microcomputer, solar energy, robotics, fiber optics, lasers, fax (facsimile), and biodegradable. While the language dimension for technological literacy

is endless, the importance of including new terms as part of our students' vocabulary cannot be overstressed.

The cognitive process of developing a facility with technical language is a key contribution of technological literacy. Often, language development involves relating terms, symbols, and objects. As indicated by Scarborough and Blankenbaker (1983), students need to be able to conceptualize the meaning of terms to develop a language dimension. Figure 8-3 illustrates the stages a person goes through to conceptualize the meaning of terms.

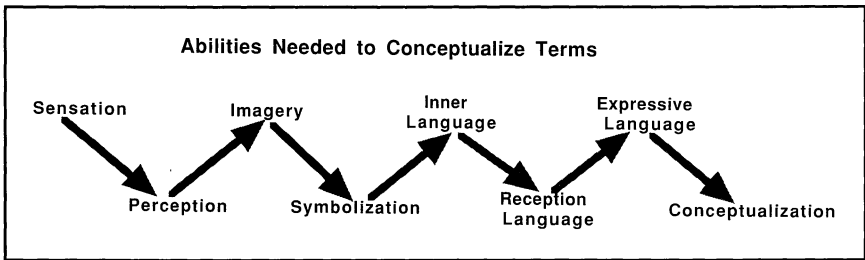


Figure 8-3. Abilities needed to conceptualize terms (Scarborough & Blankenbaker, 1983, p. 3).

To clarify this, consider how a group of high school students conceptualizes terms as they develop their technological literacy. Think of a class of eleventh grade students studying microprocessors. It is necessary for the students to comprehend the term microprocessor and relate it to a physical object and its function. In this instance, the cognitive process may begin as the students use their visual sense to gain a perception of the object. By having learned, in ninth and tenth grade, that the prefix micro means small, the students' imagery places the term in proper context. Likewise, the students' vocabulary dimension allows them to relate the term, processor, to an object that involves action taking place. The students' inner language allows them to transfer one experience to another. They may begin to think of terms which may have a relationship to the term microprocessor such as microcomputer, "microbot," microchip, or microwave. At this point of the cognitive process, students are attempting to assign meaning to the word so

that they gain an understanding of the term and are capable of using it themselves. Once students have associated the term with its meaning, they have grasped a conceptual understanding of it.

Cognitive development also contributes to technological literacy in that it provides students with the key prerequisites to perform the complex task of problem solving. This cognitive process is an essential part of technological literacy because problem solving is necessary for technological innovation to occur. Few technical developments would exist today if people were unable to think and reason and learn a problem-solving procedure. Waetjen (1989) suggested a six-step process for classroom instruction which included 1) define the problem, 2) re-form the problem, 3) isolate the solution, 4) implement the plan, 5) restructure the plan, and 6) synthesize the solution (see Figure 8-4).

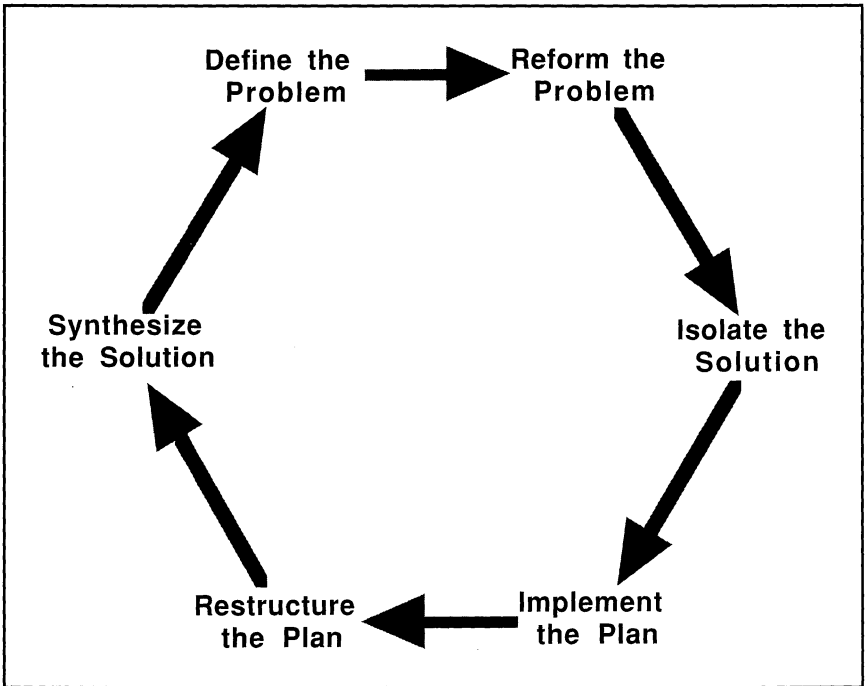


Figure 8-4. Circular problem-solving model.

Waetjen's problem-solving procedure could be used by high school students to solve simple technical problems in laboratory activities such as trouble shooting an electrical circuit. Alternatively problem solving could likewise be used when students attempt to solve more complex environmental problems such as nuclear waste, deterioration of the ozone layer, or air pollution. In all cases, when students are involved in problem solving—they use their thinking and reasoning abilities.

Sensorimotor Development

An essential part of technological literacy is the development of students' sensorimotor abilities. Perceptual and motor skills represent a major objective as technology education helps students develop technological literacy. Without such skills, students lack the ability to be tool users. Throughout history people who worked with technology (and understood it), used tools to build, modify, or generate new technologies. These same actions are taught as the core of high school technology education courses. The use of tools, equipment, and technical processes is central to common high school technology education courses such as: Manufacturing, Communication, Transportation, Energy/Power, Principles of Technology and Robotics among others.

A few traditionalists or missassigned trade and industry instructors may still view motor skill development as the chief outcome of high school technology education programs, but this does not do justice to technology education's cognitive and affective dimensions. State departments, such as Arizona, Missouri, and Illinois, have developed competency lists which indicate, in proper context, the specific technical skills students should acquire in technology courses in addition to others needed to advance students' level of technological literacy. The new perspectives and technical skill development students acquire in advanced high school technology courses are also likely to be beneficial in making a career choice and for avocational activities.

Affective Development

It would be difficult to agree that high school students are technologically literate if they could not make value judgements regarding technology and the world in which they live. The affective domain contributes to technological literacy development in that it helps students acquire decision-making abilities. Naturally, the student attitudes and beliefs influence their decisions. Technology education courses attempt to provide learning experiences for students in order

to develop their attitudes and beliefs about the world and the role they play in creating and controlling new technology. High school technology education programs develop technological literacy by helping students assemble a value system that addresses, among others:

- relationships with people,
- maintaining the environment,
- work roles,
- continuing education,
- appreciation of creativity (art, literature, invention, etc.), and
- worthy use of leisure time (Daiber & LaClair, 1986, p. 116).

Because of the maturity level of high school students, the value systems they acquire during their last years of public education are important to their ability to make wise decisions as citizens and consumers in society. The affective domain of learning must be given significant attention when designing instructional units for technology education courses so all young adults graduate from high school with the ability to make constructive decisions.

Approaches to Program Implementation

The curriculum approaches by which the enhancement of technological literacy is addressed will vary from school to school. Currently, three national programs seem to be most prominent. These programs are: Technology Education; Science, Technology, and Society (STS); and the New Liberal Arts (NLA).

Technology Education

Technology education programs to a large extent are a revision of industrial arts programs. In these programs, students learn about the technological systems of communication, construction, production, and transportation. State departments of education (e.g., Wisconsin, Illinois, Indiana, Missouri, West Virginia, Ohio, Oklahoma, Texas and Florida, among others) have organized their approach to technology education into state plans to best fit the needs of their high school students. These technology education programs attempt to make students aware of the technology in our world and the impact it has on their lives as consumers and citizens. The instructional units in high school technology education courses provide for objectives in each of the three domains. In some instances advanced technical classes such as computer-aided drafting or energy/power systems may even prepare students with a technical speciality. Other advanced technology educa-

tion courses are more science-based such as the Principles of Technology course. This latter course focuses upon eighteen applied physics units (force, power, light, sound, et al.) which pertain to science and technology. Some schools have also developed eleventh and twelfth grade courses that focus on research and development, problem solving and/or technology systems.

Science, Technology, and Society (STS)

The Science, Technology, and Society curriculum thrust represents a second approach to developing technological literacy. According to Wiens (1987), this approach teaches science to general precollege students through general STS concepts. The content of STS programs emphasizes the sociological, psychological, and environmental effects of technology and the value questions associated with them. It tends to emphasize the affective and minimize the psychomotor domains. The STS program provides opportunities to "introduce science and technology components and their societal implications into mathematics, humanities, and social studies courses" (*The S-STS Program*, 1985, p. 11), but so far it has not penetrated far into the technology education ranks.

New Liberal Arts

The New Liberal Arts programs focus on explaining the implications and consequences of science and technology. "NLA courses focus on how technologists approach problems and how technology works" (Wiens, 1987, p. 20). These courses attempt to reduce students' fears about technology. This approach to technological literacy is found in high schools that tend to maintain strong academic curriculums and consequently do not emphasize technology education as a discrete subject area.

Adaptation of the Technological Literacy Model

Senior high school technology education programs expand students' abilities so they can attain a greater level of technological literacy. As illustrated by Dyrenfurth's synthesized model (Chapter 7), the high school curriculum advances students' general education. High school students acquire a broader language dimension and knowledge base with which to comprehend the technology in our world. Through numerous experiences, both those in technology education classes and others in the general core curriculum, students increase their techno-

ogy education can facilitate their learning of abstract concepts. The strategies technology education teachers use to make their lessons action-learning classes helps some students understand the operation of technological systems, which may otherwise not have been understood.

As the maturity level of the students increases in high school so must the sophistication of their technological activities. Students who are involved in challenging problem-solving activities find it difficult to be bored with class. Students are expected to exert a tremendous effort to solve technological problems they have been assigned. Therefore, it must be necessary for them to utilize research skills and information gained in previous high school courses.

Many outcomes of high school technology education programs are illustrated by students' interpersonal skills. At the time of graduation, students' take on adult roles as consumers, employees, parents, and members of civic organizations. Their performance in society is affected by their technological capability. Therefore, it is important that senior high schools make an asserted effort to increase students' technological literacy.

ASSESSING TECHNOLOGICAL LITERACY

No matter what curriculum approach educators select to implement technological literacy, it is important that they are able to assess the learner's progress towards the goals. Initially the task of assessing technological literacy may seem impossible to teachers because, as of yet, there is no standardized instrument or procedure to assess technological literacy formally. However, there are various instructional methods that can be used in the classroom which will help teachers know the extent to which students are becoming technologically literate.

One of the simplest means of assessing technological literacy is through discussion. As a result of the instructional program, students should have expanded their vocabulary. One-on-one and group discussions allow students to use the new terms and knowledge they have acquired. Their verbal answers to discussion questions will reflect their technological literacy in terms of both breadth and depth. A teacher may wish to select several topics for discussion at the beginning of the year and tape the session. The teacher may then tape the discussions about the same topics at the end of the year. By listening to both tapes at the close of the school year, the teacher will be able to

make an assessment concerning the development of the language dimension of students.

Classroom teachers may be able to assess technological literacy through observing problem-solving activities and the results of hands-on activities. Creating posters, building models, or constructing projects are activities that allow students to learn about technology and illustrate their abilities. A series of activities may be used to assess the development of students throughout a year. As indicated earlier in this chapter, learning units should progress from simple to complex. Teachers could assess the technological literacy of students' by analyzing how well students demonstrate their knowledge of specific technological concepts at different times in the school year.

Another approach for assessing the development of technological literacy is through paper and pencil exercises. These tasks can be conducted in the format of a pre-test/post-test design. Classroom teachers may design matching exercises, short essays on a particular topic or issue, or developing a solution to a given problem.

Some instructors may want to develop a technology achievement test which would include the major objectives of the course. The test could be designed to include social, cultural, environmental, political, and technical questions relating to technology. This test would be issued at the beginning and end of the year. Students' gain scores could be used to assess their progress.

Each of the approaches that have been suggested to assess technological literacy noted the importance of **observing** student development. This point is important because any class of students may contain quite varied technological literacy levels. In fact, individual student development of technological literacy along each of the three domains may be quite disparate. Classroom teachers may want to chart each student's technological literacy development on a continuum so they can visually observe student progress in each domain. This chart could also serve as a useful focus for teacher-student interaction.

SUMMARY

Technological literacy is an important part of the education of all students in grades K-12. Teachers at all levels of education need to provide students with lessons and learning units about technology. This can be accomplished by including technology-related terms as part of

the students' vocabulary, engaging students in decision-making and problem-solving activities, and requiring students to design and build products that develop their technical abilities. The sophistication of the technology learning units must parallel the maturity of the students.

Technology education has been advanced as the logical vehicle through which to accomplish the development of technological literacy. Each teacher's active involvement in instructing students about technology remains the most significant means by which this objective can be accomplished.

CHAPTER NINE

SUPPORT ACTIVITIES FOR IMPLEMENTING TECHNOLOGY EDUCATION PROGRAMS

by
Roger Stacy¹
Harry Tobin²

Many parts of our world are designed, shaped, and controlled largely through the use of technology. Humankind has brought the Earth to a point where our future well-being will depend heavily on how we develop, use, and control technology. In turn, that will depend heavily on how well we understand the workings of technology and the social, cultural, economic, and ecological systems within which we live (AAAS, 1989).

All too often technology is right at our fingertips and yet we have little understanding of what is taking place. A case in point: is it a magic wand that one waves when pushing a button to open or close a garage door? Or is it magic to push a button to change the channel on television? Or to levitate a train?

And in a case where our level of understanding became a critical safety hazard: at a local discount store recently, the college-aged cashier experiencing frustration because a bar code on a toothpaste carton would not register on his/her laser scanner, stared down into the "bright red light" and commented "This thing hasn't worked right all day." Why didn't this person know that the scanner contained a Class II Helium Neon laser capable of doing irreparable damage to eyes?

With the education profession's moves towards the future, we are incredibly fortunate to have visionary leaders who design and develop

¹Roger Stacy is the Supervisor for Technology Education, in the Division of Vocational Education, Oklahoma Department of Education, Stillwater, Oklahoma.

²Harry Tobin is Director, Bureau of Industrial Technology Education, Chicago Public Schools, Chicago, Illinois.

21st Century conceptual frameworks and curricular models aimed at delivering technological literacy. It is our responsibility to interpret and respond to those futuristic recommendations using realistic terminology and feasible activities which our newly transformed technology education teachers can understand and then deliver to students in grades K-12. It is exhausting but challenging work.

To successfully **merge** what our profession's theorists say we should do—with what public school teachers, who have long been producing copious amounts of sawdust, think—could easily be considered "a significant emotional event" for any state or local supervisor. As recommended by former U.S. Commissioner of Education, Ernest Boyer (1985), the technology education profession must translate our visionary documents, which prescribe a futuristic framework for the curriculum, into a practical prescription for the school and classroom/laboratory. The front-line supervisor is principally responsible for the success of this enterprise.

We must not overlook the fact that, even though we are loathe to admit it, the majority of our teachers may be still teaching traditional woods and drafting and many have little innate desire to initiate a curriculum targeting on the study of technology. Do we give up on these teachers and wait for their retirements? Do we support them and assist them to become better traditional teachers? Or do we work with them on a month-to-month, conference-to-conference, visit-to-visit basis to gradually alter their attitude to a more global view of a technology-based curriculum? Can we possibly effect a change in their traditional approach?

Most likely, the one area where the majority of the emphasis should be placed in the initial stages of change is on the **attitudes** of the teachers, administrators, teacher educators, and other supervisors. These attitudes will have to bend, even if only ever so slightly, if we are to start addressing technological literacy as the prime mission of technology education.

To accomplish this, it is imperative to establish a nucleus of supportive, innovative, and futuristic-thinking teachers to start the change process. It is the receptiveness, and hopefully even a "hooked on technology" attitude, of these significant groups that holds the key to the modernization of existing programs. This "attitude adjustment" in the opinions of supervisors ranks at the "top of the pole" of importance when the implementation of technology education is being sought.

Fortunately, there has already been a philosophical turn-around related to technology education programs throughout North America.

Central to this process have been the systematic efforts of many states and large school districts. To move a philosophical idea to implementation in a large district is a lot like moving the pioneers across our great country to find a new life. In order to survive and eventually settle and thrive, these hearty souls needed support! The pioneers in technology education are the "early adopting" instructors, and they need support to survive in their schools as well as to refine their instruction in advancing technology.

PERSPECTIVES: STATE AND LOCAL

The State Perspective

Providing leadership, supervision, and direction within a profession which is being challenged to simultaneously address both survival and futuristic technologies is not only extremely challenging, but often-times very frustrating. This is all the more true when reflecting on the supervisor's actual powers. Answers to critical questions related to definition, mission, philosophy, curriculum, methodology, evaluation, teacher education, certification, teacher recruitment, and numerous other areas have been found, time and time again, to be despairingly elusive. And when some answers finally emerge, often they are vague, ambiguous, and open-ended.

It is a grand understatement to say that the transformation from traditional industrial arts to technology education is a difficult one. The primary person, in most cases, with whom the responsibility lies to initiate and negotiate this change successfully, is the state supervisor. From the perspective of a state supervisor, the situation seems to be best defined as a "package deal." When prioritizing the support activities and services needed, too much emphasis on some areas while overlooking others could prove to be detrimental either by delaying the conversion to technology education or even being fatal to one's career.

The so-called "package deal" approach involves several additional key areas which must be considered necessary elements of a successfully organized, supervised, and administered technology education program. Although not in rank order, the establishment, development, and inclusion of each of these areas is imperative for support of a complete technology education program that viably addresses the development of technological literacy:

- a published state-level mission statement, including goals, learner outcomes, and criteria,
- a 21st Century Technology Task Force or Advisory Council,
- curriculum content which is based on technological literacy, the integration and application of academics, basic skills, problem solving, critical thinking, creativity, and other pertinent areas,
- contemporary and systematic instructional methodology,
- quality, systems-oriented instructional materials,
- student organizations,
- effective program funding,
- facility renovation,
- equipment needs,
- local advisory councils,
- teacher preparation, certification, and examination,
- teacher and teacher educator inservice,
- high school graduation requirements,
- advocacy by teacher educators,
- program evaluation and visitation,
- public relations and marketing,
- legislative involvement,
- professional organizations,
- recruitment of teachers,
- compliance with federal legislation,
- research,
- conference planning,
- articulation with vocational courses, and
- personal professional development.

When pursuing many of the listed elements, a state will reach temporary plateaus after relatively focused short-term emphases brings about fruition. Then states may temporarily place these elements "on the back burner." Supervisors, however, must be careful to see that these elements are not forgotten. They must work to see that they become ingrained into the profession's being.

The Local Perspective

With the advent of many changes in philosophy regarding what should be taught in technology education and what approach should be used to accomplish old and new curriculum objectives in large school districts, it is vital that a "central office person" be available to take on a key role in helping the transition come about. This heart of

the role is to provide the support necessary to implement technology education's objectives and, at the same time, to continue to provide teachers with meaningful, up-to-date activities related to the world of technology of today and tomorrow.

To support, Webster tells us, is: to endure bravely or quietly; to promote the interests or cause; to uphold or defend as valid or right; to argue or vote for; to assist, help. The synonyms for support he lists as: uphold, advocate, back, and champion. Each of these definitions and synonyms has a special place in the memory of most city directors/supervisors. An administrator sequestered in the central office of a large city school system, developing strategies in isolation, would never be able to effect the across-the-board acceptance a successful implementation requires. To expect a philosophy to be implemented simply by stating it is naive.

IN SUPPORT OF CHANGE

Program/Curriculum Development Mechanisms

Once the leadership within the technology education profession of a given state or district determines the need to move from industrial arts to technology education, it usually becomes the responsibility of a supervisor to formulate a grand strategy. Often a task force or advisory council of some type is used to establish the plan. These groups are typically endowed with progressive-sounding names such as the 21st Century Technology Task Force or the Technology Task Force 2000.

The mission of such groups should be to design and develop the "total" program of technology education, ranging from determining learner outcomes to establishing the legislative lobbying efforts necessary to provide the new programs with financial assistance. There should be no frustrations if it takes 8-12 monthly meetings of this council before significant outcomes are realized. It might even take as much as three years before there is some feeling of accomplishment. The curricular renaissance the technology education profession is undertaking is major in scope and it will take time—even under the best of circumstances.

The appropriate and workable size of the group, for many states, has been the 25-30 persons range. Those selected to serve should be visionary and futuristic and must definitely be open-minded. Consideration should be given for the inclusion of persons such as: (a) technology

education teachers, (b) technology teacher educators, (c) public school superintendents, principals, and counselors, (d) parents, (e) educational theorists and futurists, (f) state department of education representatives, (g) vocational educators, (h) business and industry representatives, (i) state and national leaders in the profession, (j) academic and basic skill representatives, and (k) at-risk and handicapped population representatives. Most importantly, these persons must be able to think and conceptualize from a global perspective, while at the same time provide local and realistic applications of technology. Each person's political value and influence also needs to be considered although this should not outweigh the other characteristics.

Key Elements of Technology Education Plans

As agendas for their meetings are planned, it is imperative that outside trend-spotters and industry representatives address the group. Also important are site visits to pertinent and applicable futuristic situations—preferably on a regularly scheduled basis. It may even be appropriate to conduct public hearings to air concerns of subgroups which may wish to provide input either for or against the "technology-oriented" cause. The task force should address and strive to ascertain answers to questions such as:

- What is technological literacy?
- How should technological literacy be delivered to students?
- At what grade level should activities addressing technological literacy first be introduced?
- How does technology education fit into the total educational plan?
- What students are going to be served: gifted, special population, minorities, handicapped, etc.?
- Who will the teachers be and how will they be inserviced?
- What are the roles of the counselors, administrators, parents, business leaders, teacher educators, state staff and other key persons as the technology education program is implemented at state and local levels?
- What set of standards should the program's evaluation criteria be based upon?
- How often should revisions be made to the conceptual framework being used as the model?
- What are other states doing in a similar vein?
- What role does a student organization play in delivering technological literacy?

- Who will retrain the teacher educators in order for them to provide quality and practical application instruction in the preparation of technology education teachers?

These questions represent only the beginning of the attention necessary to the critical elements of the technology education implementation process. By no means should they be perceived as exhaustive.

Key Methodological Questions

One area of concern that needs special attention by the task force is the method through which the curriculum will be delivered. Due to the nature of this new curriculum, the delivery parameters are significantly different from those experienced when teaching traditional woods or drafting courses. First, the instructional methodology will be based upon problem-solving teams, critical thinking groups, and creativity interaction circles. Individualized instruction also is a key in the delivery of technological education. In some cases, for example, as many as 20 different two-person learning stations are activated on an eight-day rotation schedule during a 45-minute class period (Hawkins & Harder, 1988). This offers a fast-paced, action-oriented, exploration experience in numerous technologies.

A second area of concern is the need for many new instructional materials, ranging from textbooks and instructional guides to learning activity packets (LAPs) and state-of-the-art video materials. The evaluation and adaptation of these materials is crucial to the alignment and articulation of the program's goals, objectives, and learner outcomes. If competency-based technology education instructional materials are sought, the Mid-America Vocational Curriculum Consortium (MAVCC) has published a dynamic series of contemporary curriculum guides. If additional help is in developing technological literacy through student organization activity, there are also exemplary guides published by the Technology Student Association (TSA) national office.

A third area of concern is the renovation of the facility. In order for technological literacy to become a real outcome of a technology education program, the facilities must be redesigned (CS-ITEA, 1989). Rather than having a complete laboratory for woodworking and a separate one for drafting, a technology center should be created which will present an environment of dignity and integrity to which the modern technologically literate person is entitled. The center should provide the latest in professional-looking technology activity centers; complete audio-visual capabilities; fresh and modern color schemes; appropriately carpeted areas; contemporary furniture including desks, tables, and

chairs; a completely climate-controlled atmosphere; a scanner grading system; and finally, an electronically-controlled security alarm system, among others.

To compliment the center's "21st Century aura," modern technology-based experimenters and trainers should be acquired and utilized in such a manner that each student has the opportunity to experience, for example, laser or satellite technology through hands-on activities. Not available just five years ago, there are now numerous trainers on the market, designed specifically for the technology education curriculum and affordable in price. Furthermore, the vendors of the products place a major priority on service which has been proven to be a definite need.

Program Management and Support Activities

As educators, we know that the "meat" of providing technology education to students is in instructional content, supporting equipment, and a well-trained instructor who utilizes effective delivery methodologies. But equally important to the integrity of the program is the overall image that is conveyed by the instructor, the students, and by such things as the facility, the titles of course offerings, and the sign above the classroom/laboratory door. The image of our profession is changed dramatically when administrators and other teachers in the school see the transformation of a woodworking shop to a technology education laboratory.

A Matter of Image

Without even entering the doors of the classroom/laboratory to see the aforementioned "meat," the transformation should be obvious. The "Wood Shop" sign outside the classroom/laboratory will have been replaced by one that reads "Technology Education." The instructor will be wearing slacks, a nice shirt, and perhaps even a tie (if the instructor is a male). There will be no massive key chains hanging from the belt loops (as all janitors and shop teachers have worn for years), nor will there be a carpenter's rule and five to seven pens and pencils stuck in the front shirt pocket. Instead, he/she will truly look the part of the "school's technologist." The instructor will have a close working relationship with the English, math, and science teachers so that projects between technology education and these subjects help students see the application of basic skills in a technological setting. There will also be a close working relationship with the counselor(s).

The counselor(s) will have observed the technology education program in action, and have been updated by the instructor on the goals and objectives of the program and the benefits available for students. Most importantly, parents, teachers, and administrators will hear the students and observe their enthusiasm. Students are by far our best "promoters" of technology education. Who would not be impressed by a seventh grader who can explain the functioning of a robotic arm like the ones used at General Motors in car manufacturing? Or what parent would not stop and take note of their eighth-grade daughter who can discuss the impacts of technology upon our society, culture, and environment as we move toward the 21st Century?

The situation just described is certainly ideal, and it is not implied that all these things can miraculously occur at once. The transformation is slow but it begins with teachers and supervisors working together. The ability to instill that "hooked on technology" feeling is crucial for all involved.

Building Cohesiveness

When the transformation process first begins, the group of interested instructors is typically rather small. This characteristic can be used to the advantage of the supervisor who is trying to implement a state-wide technology education program. With even a relatively small nucleus of true supporters, pessimistic views can be dispelled and a feeling of unity can be nurtured. Building an "all-for-one and one-for-all" attitude with the initial group is **key** to making others want to be a part of this new image. It also provides a network early on in the transformation process through which instructors can help each other as challenges arise.

Many times this new approach is the force that changes a nearly "burned-out" teacher into a revitalized, motivated, and enthused instructor. Some recruits jump on the "bandwagon" quickly; others are more slowly converted. Attention to this conversion process must be continuous as new players join the group and as occasional opposition is confronted.

With ever-present attention to attitudes, the next step must be to provide the necessary professional improvement opportunities so that instructors can become competent teachers of technology. Present graduates for the most part are prepared on a higher "technological" level than even those of just three to five years ago, but are they at the level they need to be? In a recent survey conducted at Southwestern

Oklahoma State University, graduates and student teacher interns were asked to address their level of preparedness as they entered the teaching profession as technology education teachers. Over and over again, the respondents indicated frustrations of not having a clear direction nor adequate understanding of a conceptual framework based upon technological literacy.

Typically, at least two weeks of intensive training are needed to prepare instructors on the goals of the curriculum, equipment needs, how to set-up the classroom and laboratory, and to begin specific training on problem solving, critical thinking, computer literacy, CAD-CAM, CNC, fiber optics, etc. Concurrent sessions are very effective for the specific training because it allows the instructor the flexibility of attending those sessions where he/she needs the most help. Additional inservice can be provided through district professional improvement meetings where instructors meet after school for a training session and the exchange of ideas/experiences. Working with teacher educators to provide opportunities through colleges and universities can also expand the in-service opportunities for teachers. Particularly well attended are the one- to two-week short courses or seminars offered at regional universities. Another approach is to schedule ten one-day training sessions during the summer at various locations and times across the state. If an annual state-wide teachers' conference is held, this is another opportunity for providing information and training to instructors. Whatever the avenue and vehicle for delivering the necessary teacher preparation activities, the "leaders," or task force members as previously identified, need to have input and to provide both philosophical and verbal support.

Insuring Continuing Input

Once instructors have been inserviced and a technology education program is in place, one area that deserves special attention is the establishment and effective use of a local advisory council. Such a committee includes business and industry representatives, parents, school counselors and principals, and vocational and academic teachers. It can provide localized direction to curriculum content, enhance community support, identify field trip and guest speaker opportunities, and contribute equipment, supplies, etc. to the program. And these are just a few of the benefits typically derived from such groups. Generally speaking, strong technology education programs have strong advisory councils that are utilized on a regular basis throughout the school year.

Monitoring Programs

The supervisor's responsibility to monitor program quality and to provide technical assistance which will enhance program quality is a time consuming but critical endeavor. These supervisory tasks are critical in providing direction to programs so that they can be kept "on target." Building quality programs is essential if legislators, administrators, parents, state directors, and others are to be convinced that continued or increased funding will positively impact more students becoming technologically literate.

Ideally, on-site visits should be made by supervisory staff. Unfortunately, many states do not have the staff nor the dollars to support such activities. And yet, program visitation can be one of the most important aspects of a supervisor's job. It provides opportunity to work with the instructor on a one-to-one basis, to provide technical assistance, to get a "feel" for the challenges faced daily by instructors, to work with the administration of the school to address the strengths and needs of the program, and to see "first hand" the enthusiasm of students learning about the technologies around them.

While program visitations provide formative evaluation and follow-up opportunities, when used with a more formalized summative evaluation process, they also can be extremely effective. In fact, the two can become so entwined that it is sometimes difficult for the activities to be differentiated. Formal program evaluations are usually conducted on a regular time schedule, such as every five years. Supervisory visits are usually made at least annually if not more often.

Since many states employ teacher evaluation programs, that are conducted on the local level by school administrators, it is critical to make a clear separation between program evaluation and teacher evaluation. Program evaluation should focus on those aspects that impact the delivery of quality technology instruction. Evaluation instruments should be built around these identified quality indicators. A criterion-referenced approach in the evaluation instrument and process is particularly effective. Evaluation instruments are usually built around categories similar to the following which are found in the *Summary Evaluation for Technology Education* (Oklahoma Department of Vocational and Technical Education, 1989):

- instructional planning and organization,
- instructional materials utilization,
- qualified instructional personnel,
- enrollment and student-teacher ratio,

- equipment and supplies,
- instructional facilities,
- safety training and practices,
- advisory committee and community relations,
- vocational student organization, and
- student accounting and reports.

Specific criteria should detail each area to encompass the critical and unique components of a technology education program. Beyond the state and/or local assessments, often it is valuable to use other tools as well. For example, national association and accrediting agency guidelines can be used in this manner.

The *Standards for Technology Education Programs* (Dugger, Bame, & Pinder, 1985) identify ten standards including philosophy, instructional program, student population served, instructional staff, administration and supervision, support systems, instructional strategies, public relations, safety and health, and evaluation process. In accreditation, the National Study of Secondary School Evaluation identified in its instrument, *Evaluative Criteria*, sixth edition (1987), the major categories for the evaluation of technology education programs. These were: major expectations of the program, follow-up to previous evaluations, organization for instructional program, facilities and equipment, the learning climate, evaluations and judgments, and recommendations made by the visiting team.

The evaluation process should include a self-assessment by the instructor and an on-site review by a team comprised of a state supervisor and a peer technology education instructor. The same instrument can be used for both components of the process. The self-evaluation should be reviewed and considered by the team as they complete an identical evaluation instrument. The team should recognize program strengths and commendations as well as identify areas of concern and formulate recommendations for improvement. The norm-referenced viewpoint of the state supervisor by which a comparison (even subconsciously) is made of this program to all others in the state, the expertise and experiences of the peer teacher, and a criterion-referenced evaluation instrument work amazingly well in combination to enhance the evaluation process and the ultimate decisions.

Program strengths and recommendations identified by the evaluation team should be shared with the instructor and with the administration of the school through an exit session if possible. Certainly a written report is a minimum. While the focus of the evaluation is not on the teacher, it can be very helpful if the personality and philosophy of the

instructor is known. To maximize the effectiveness of the evaluation findings, the recommendations should be written so as to be clear and concise but without being offensive. A traditional teacher who has been in the classroom for twenty years must be handled differently than a first-year teacher fresh out of college. The experienced supervisor knows how to work with the "crusty old timer" as well as the "rookie" to effect program improvement.

Providing Technical Assistance

It is at this point that technical assistance should be provided. For example, if the instructor needs ideas for facility renovation, the state supervisor could arrange for the instructor to visit an exemplary program facility or perhaps schedule a day to spend with the instructor to work on renovation possibilities.

Follow-up on the recommendations and progress made toward implementation is also crucial to successful supervision. As program visits are made on an annual basis or throughout the year, these recommendations should be monitored and progress documented. A program visitation form such as the one shown in Figure 9-1 can be used for this purpose (Oklahoma Department of Vocational and Technical Education, 1989). This never-ending circle, with program improvement as the central focus, is a vital segment of a supervisor's role.

Administrative and Liaison Support Activities

The administrative and liaison support activities seem best defined as the "nuts and bolts" or "behind the scenes" activities of the profession. There exist several extremely critical areas which must be addressed on a day-to-day basis by utilizing specific committees, advisory councils, task forces, and informal but official one-on-one conversations between the state supervisor and key appropriate leaders within the profession. In most every state, just as on the local or even national level, numerous critical administrative decisions must be made expeditiously without the resource of a formal committee, and it is those key phone calls between the internal leaders where the profession establishes the "backbone" or "foundation." A state supervisor must determine where the "visionary thinkers" are located in a state in order to address "what truly needs to happen" to implement technology literacy as a curricular objective.

**Oklahoma State Department of Vocational and Technical Education
Technology Education**

School _____ Supervisor _____
 Program _____ Teacher _____ Date _____

	SM	NI	NM	NA	NO
1. Instructional Planning and Organization Learning activities are properly planned and organized and are being sequentially implemented as evidenced by: Course outline _____ Lesson Plans _____ Long-Range plans _____ Four Clusters _____ Filing System _____ AVTS Visit _____ Well-Defined Grading System _____ Students Working on Assigned Project _____ Basic Skills Articulation _____ Parent Overview _____ Terminology _____ Multiple Activities _____ Guest Speakers/Field Trips _____ Problem Solving _____					
2. Instructional Materials Utilization The teacher has access to and properly utilizes the following instructional materials: State-Approved Curriculum Materials - Teacher _____ Student _____ Related Audiovisual Materials _____ Individualized Instructional Materials _____ Library _____ Progress chart _____ Competency Profiles _____					
3. Qualified Instructional Personnel* a. The teacher takes active measures to ensure professional growth through regular attendance of: *Summer conference _____ *Mid-Winter Conference _____ Professional Improvement Plan _____ *Professional Improvement meetings _____ *Workshops _____ *Memberships _____ b. The teacher holds the following teaching certificate: Standard _____ Provisional _____ Emergency _____ License _____					
4. Student-Teacher Ratio Enrollment limits (min./max.) are maintained within state guidelines _____ Current enrollments are: 6th _____ 7th _____ 8th _____ 9th _____ 10th _____ 11th _____ 12th _____ Scheduling Conflicts _____ Pre-enrollment Presentation _____					
5. Equipment and Supplies* a. The equipment and supplies are of sufficient quality and quantity to carry out instructional goals and objectives. *Required Equipment _____ Updated Equipment _____ b. Needed items of equipment and supplies are requested (in writing) and purchased on a timely basis _____ Amount of Incentive assistance _____ Repairs Needed _____ c. A long-range plan has been developed for equipment replacements/additions _____					
6. Instructional Facilities a. The instructional facilities are of sufficient quality and size and contain the following components: Classroom _____ Lab _____ Office _____ storage _____ TE Sign _____ Cleanliness _____ Organization _____ Integrity/Dignity _____ b. The instructional facilities provide a conducive learning environment with appropriate amounts of: Heat _____ Light _____ Ventilation _____ Painting _____ Learning Stations _____ Telephone _____					
7. Safety training and practices a. The following equipment and facility safety features are maintained and periodically reviewed: Lab and Equipment Color Coding _____ Electrical Wiring _____ Protective Clothing and Equipment _____ Storage of Explosive and Caustic Materials _____ Fire Safety _____ Other _____ Signs _____ Hazardous Communications _____ b. Safety is taught and practiced in instructional activities _____ Following Safety Steps _____ Eye protection used _____					
8. Program Advisory Committee A program advisory committee is utilized to support program goals and objectives as evidenced by: Membership Listing _____ Minutes of meeting _____ other _____ Number of Meetings held Last Two Semesters _____ Follow-Up on Recommendations _____					
9. Vocational Student Organization* a. All students are afforded the opportunity to participate in the leadership development activities as evidenced by: Timely Chapter Affiliation _____ Local Meetings _____ Officer Training _____ Competitive Events _____ Community Support _____ b. Student organization activities are an integral part of the course of study _____ Percent membership _____ c. Students are actively involved in a broad range of leadership development experiences _____ FLC _____ Chapter President _____ State Conference _____					
10. Coordination Activities--Not Applicable for Technology Education					
11. Student Accounting* a. Student enrollment, completion, and follow-up data are completed and submitted on a timely basis as required by the state agency _____ b. Efforts are made to assist program completers in job placement _____					
12. Adult Education Adult education activities (if applicable) are conducted. Number of Contact Hours _____					
13. Records Management* Forms/Reports to be turned in: Salary and teaching Schedule _____ Student Accounting _____ Annual Curriculum Chart _____ Laboratory Floor Plan _____ TSA Chapter Affiliation _____ Instructional Materials _____					

*To be recorded on master chart
 See attached page for narrative comments -- Equal opportunity/Affirmative action Employer

Figure 9-1. Program visitation report (OK).

Support Activities for Implementing Technology Education Programs

Some of the administrative and liaison support areas where action must be taken to ensure that all "bases are covered" to implement technology education include: (a) working directly and deliberately with all teacher education institutions in the state which prepare technology education teachers, (b) working with state educational agencies and regulatory boards which administer textbook adoption, teacher certification, program accreditation, teacher examination and licensing, high school graduation requirements, program titles and terminology, program research and testing, program evaluation, and finally, curriculum articulation with math, science, English, and other subjects.

Additional areas which must be included within the priorities of administration involve working directly with the leadership of the technology teacher's professional organizations, literally leading and prodding key teachers and teacher educators to get involved in the legislative lobbying efforts; working directly with federal representatives to administer compliance activities relative to federal legislation requirements; and not to be taken for granted, the ongoing public relations and promotional activities dealing with technology education.

And finally, and possibly the most crucial areas which supervisors must address, are: technology teacher recruitment, program funding, and the interface of proper and appropriate activities to insure camaraderie among all teachers, teacher educators, and supervisors within the technology profession. These attitudes time and time again hold the key to the true implementation of the new programs.

The source of our future teachers is an open question. There seems to be no clear cut answers with the exception of the utilization of the Technology Student Association (TSA). The competitive event structure and leadership activities now provide over fifty specific events directly related to technology literacy and exploring teaching as a profession. TSA is incorporated successfully into numerous technology education programs as an integral part of the technology curriculum.

And to expand briefly on program funding, there seem to be several areas where state financial assistance does make a difference. Over and over again leaders in our profession boast that technology education can be taught without financial assistance. But when one talks to the technology education teacher in the classroom, the opinions are that "financial assistance will definitely enhance and improve the level of instruction and delivery of technological activities." Examples of needs include technology equipment, teacher inservice, teacher salary

supplements, teaching supplies and materials, program research, and travel reimbursements for teachers and students.

CASE STUDY: ONE STATE'S APPROACH

Technology Education in Oklahoma has been extremely fortunate since June 1985. The state has been able to transform the offerings of over 100 traditional Industrial arts programs into modern state-of-the-art technology education programs. Many significant factors have enabled this curriculum reform effort to become reality. A review of the past ten years of development of technology education in the state identified the following items as being critical to its present success and its future development.

Establishing the Initial Rationale

Even though the state leaders within technology education are not widely known nationally, the state is blessed with teachers and teacher educators who are truly committed to excellence, have proven time and time again to be visionary thinkers and movers, and constantly strive to design and develop exemplary content and methodology that meets the needs of our Twenty-first Century society.

In 1983, a state-wide 21st Century Technology Task Force was established to address specifically the rationale necessary for curriculum revision within the state as well as to determine exactly what the mission of the new curriculum should be. Some of the elements addressed were:

- Technological literacy in the next century and to what extent Technology education could provide realistic and relative learning activities.
- The nationwide movement to revitalize the entire educational spectrum.
- The declining enrollments which were leading to the elimination of many of our traditional programs.
- Apathetic teachers and low self-esteem because, among other things, their classes were considered the "dumping ground" for the school system.
- The need for leadership development activities to be incorporated as an integral part of the curriculum using TSA as the delivery tool.

Support Activities for Implementing Technology Education Programs

- The need to provide career awareness and experiences for all students enrolled.
- The need to get teacher education "up-to-speed" to train and retrain Technology education teachers.

This 30-person task force was made up of futuristic minded Industrial arts teachers and teacher educators, public school administrators, parents, educational therapists and futurists, State Department of Education leaders, vocational educators, business and industry representatives, academic and basic skill representatives, at-risk and handicapped population representatives, and national leaders within our profession. After 18 months of meetings and ongoing sub-committee work, the task force submitted a strategic plan to the State Board of Vocational and Technical Education which included purposes, goals, objectives, curricular direction, funding requirements, and the overall implementation plan for the new technology education programs. This was a major hurdle since never before had our profession received major financial support for industrial arts programs. Subsequently, approval was granted primarily due to the efforts and support we received from Dr. Francis Tuttle who "championed our cause." The next step was to get approval through the state legislature.

Securing Funding and Support

Never having lobbied before, the profession's task force felt somewhat intimidated as they approached the senators and representatives for over \$2 million to fund 50 new programs. (The expenditure breakdown per program consisted of \$20,000 for equipment, \$4,500 per year for materials and supplies, \$2,000 for salary supplement per teacher and \$700 per teacher for in-service training).

And even though our 20-person lobbying team held "rookie" status, it had a salable product in technology education (somewhat parallel to motherhood, baseball, and apple pie). The legislators were so excited to hear of our attempt to improve and replace the traditional "S-H-O-P" curriculum with one which was technology-based, provided problem-solving and critical thinking experiences, and integrated leadership in the daily curriculum, that they literally recommended that we make technology education mandatory in each of the 350 middle and junior high schools in our state at a cost of over \$5 million.

Even though this was an excellent opportunity to take a giant step toward improving our programs, we felt it was truly "too much too fast" and optioned to develop a five-year plan to implement 250 pro-

grams. The primary reason for the delay was to allow time for traditional IA teachers to become more familiar with the program which hopefully would enhance the success of the programs and any future programs through the year 2000. It was extremely important to have teachers **want** to implement technology education rather than be **made** to implement technology education. We believe that the attitude of the teacher is the single most important factor in implementing a successful technology education program.

As it turned out, the following year and subsequent three years brought the "oil boom" to an "oil bust" and funding for our program was limited to less than a million dollars per year. Even though this was less than planned, we still felt that any funding going to our program was significant because school after school would lay off teachers due to devastating financial woes, but yet somehow would jump at the chance to allocate the \$10,000 in order to match state funding for a new technology education program in their school. At the present time the state starts and funds new technology education programs on a yearly basis and there is an annual waiting list of over 100 schools requesting funding.

Key Quality Determinants

Technology education in Oklahoma is an instructional program that provides young men and women (grades 6-10) with daily, hands-on exploratory experiences and insights into technology and career opportunities so that they can make meaningful occupational and educational choices. It is a program for all students whether they are valedictorians, salutatorians, student body presidents, or those students who have found little success in school (at-risk students). With the limited number of elective courses during high school, today's students, more than ever before, need to be exposed to as many occupational choices as possible. The technology education curriculum provides these experiences.

"Technology education instructors teaching technology in a laboratory" replaced the phrase "shop teachers who teach shop in a shop." Teachers emphasize integrity, dignity, pride, and positive attitudes. In addition, the TSA is implemented as an integral part of the curriculum to provide leadership development activities for all students.

All technology education courses are taught in a one-period block of time (45-55 minutes), with each of the four technology systems (communications, construction, manufacturing, and transportation)

designed to articulate with other courses offered in comprehensive schools (e.g., math, science, English, agriculture, and home economics), as well as in the area vo-tech schools. Interdisciplinary education is vital to the success of these programs.

Indicative of the state's perception of needs for the 21st Century's society, the curriculum was developed around the following learner outcomes. Each student should have the opportunity to:

- Know and appreciate the importance of technology and technological literacy.
- Explore career opportunities so they can make meaningful occupational and educational choices.
- Apply problem-solving and critical thinking techniques.
- Apply math, science, reading, and other school subjects in a practical situation.
- Develop keyboarding and computer literacy skills.
- Apply tools, materials, processes, and technical concepts safely and efficiently.
- Uncover and develop individual talents.
- Think logically and sequentially.
- Become a leader in a technological society.
- Become a wiser consumer.
- Adjust to a changing environment.
- Deal with forces that influence the future.
- Develop an understanding of economic development.
- Communicate by making clear and relevant points.
- Develop positive self-concepts.
- Apply design, imagination, and creative abilities.
- Further the development of lifelong learning skills.

It has been proven many times over in each of the vocational divisions that student organizations play a vital role in supplementing technical curricula with the essential elements of leadership development. Student organizations, e.g., Technology Education-TSA, Agriculture Education-FFA, Home Economics-FHA/HERO, Trade and Industrial Education-VICA, etc. are necessary to achieve a proper blend of technical exposure and leadership development which provides students with exemplary learning experiences and personal and professional growth opportunities.

Even though the involvement of our profession in TSA on the national scale is relatively low, in Oklahoma TSA is used as a primary catalyst on which to build technology education programs. Through the

leadership of Harold Holley and Donovan Bowers, the Oklahoma TSA state advisors, TSA has become an integral part of each technology education program.

Businesses and industries today are seeking employees who possess more than just technical skills. They need employees who exhibit good work ethics, attitudes, and values, as well as positive attitudes toward fellow workers. In addition, industry is seeking employees who are well-groomed, can "dress for success," can speak and present points clearly, can understand and use parliamentary procedure, and exhibit high moral beliefs and standards.

Finally, it is the state's position, that the technology-based competitive events within TSA are extremely beneficial to teaching technology in the laboratory. TSA's five-year plan to incorporate additional technology-based events is timely and offers systematic learning activities in an environment which enables students to make more meaningful choices related to future occupations and/or continued education.

Overview of Key Steps To Technology Education

The success Oklahoma has experienced in implementing technology education is largely due to several strategic actions employed to bring visibility and integrity to the programs. Some of these strategies were:

- Became part of the vo-tech family,
- Used TSA as a "spring board,"
- Had technology education teachers join professional organizations (Oklahoma Vocational Association/American Vocational Association, Oklahoma Technology Education Association, International Technology Education Association),
- Worked with traditional industrial arts teachers concerning acceptance of new programs,
- Developed technology education professional improvement (TI) districts state-wide,
- Involved technology education teacher educators in the development of the new programs, certification standards, teacher certification test revision, teacher inservice, and strategic planning,
- Worked to make technology education more visible through radio, television, and newspaper spots,
- Worked to enable all state educational agencies involved to understand the program,

Support Activities for Implementing Technology Education Programs

- Changed the name of our teachers' association (unanimous vote) to the Oklahoma Technology Education Association (from Oklahoma Industrial Arts Association),
- Changed name of programs to Technology Education (from Industrial Arts),
- Discontinued use of the term "shop" in the state,
- Lobbied the state legislature for funding,
- Developed a program which met our state's needs of improving the quality of education,
- Continually worked to make teachers feel good about themselves and their programs (i.e., integrity, dignity, pride, and positive attitudes),
- Evaluated and visited each program annually, and
- Worked closely with MAVCC, Agency for Instructional Television, and NASA to develop instructional material for technology education.

The redesign of Oklahoma's technology education curriculum into a modern, viable program for today's young people was extremely fortunate to have had the support of Francis Tuttle, former state vocational education director; Roy Peters, current state vocational education director; and Ann Benson, assistant state director. The state's teachers are full of energy as they now project a new-found feeling of pride, enthusiasm, and high self-esteem. In addition, they feel they are now highly respected by fellow teachers and administrators in their local schools. Technology education no longer is the "dumping ground."

Teachers with 3 to 25 years experience indicate that never before have they seen students get so enthused as they have about the projects and activities in their technology education classes. These are the same teachers who were hesitant and even against starting a TSA chapter. Now they are strong believers that leadership development for their students is vitally important as they explore career opportunities in an ever-changing technology-based society. They are convinced the TSA is the "way to go."

Oklahoma's profession is experiencing a long-awaited excitement which will get even stronger as each year passes and additional technology education programs are established within the state. Presently, technology education is even listed as a course to be mandated for middle and junior high schools in a massive state educational reform bill. The pace is fast and furious. Technology education's time has truly come!

CASE STUDY: ONE LOCAL APPROACH

Chicago Public Schools' central office wholeheartedly accepted the challenge of effecting change in technology education. It welcomed the opportunity to contribute in such a major way to the advancement of this field. Without the central office's total acceptance of the idea from the beginning and without the collaborating action of the city and state's technology education leaders, most teachers would have been content **not** to pursue the changes. Certainly the enthusiasm for industrial arts reform was not shared by many in the district at the outset. The commitments necessary for the curriculum changes were constantly challenged by teachers, administrators, and others. Although objection to change is a common reaction, the attitude of some industrial arts teachers now assigned to teach technology education was one of active resistance. For full-fledged implementation of curriculum change, consistent and specific support was absolutely necessary. The follow-up during and after training and implementation was also crucial to the success of the initiation process.

Implementing a technology-based curriculum among instructors of diverse backgrounds, most of whom were skill-oriented and single-minded, was a tremendous challenge. The methods of support necessary to accomplish this with hundreds of teachers in one district were as varied as the individual teachers and the facilities in which they teach. Experiences ranged from an encouraging word, to providing incentives beyond the intrinsic, to full-scale rehabilitation of a facility to accommodate the teaching of modern and futuristic technology. Webster's first definition of support, to endure bravely or quietly, was artfully demonstrated by the leaders who influenced the industrial arts teachers to teach technology. Outside organizations and individuals provided significant amounts of support for the teachers. Among these were state consultants, college professors, principals and teachers from other districts and private schools, community service persons, business professionals and industrial technicians, students, media, advisory groups, and parents. Funding was provided by the Illinois State Board of Education and the Department of Adult Vocational and Technical Education.

Evolution of the Plan

The implementation of the Illinois Plan in the Chicago school district involved many key steps. Among them were the following. All embody the principles of effective supervision:

1977-78: The first meeting of the Industrial Joint Staff convened at the Illinois Education Association Conference in Peoria, Illinois in February, 1978. At this meeting, the development of a new State Guide was identified as a high priority. Subsequently, a prospectus was developed and an RFP was let.

1978-79: Funding was received by the University of Illinois to: (a) review the literature and obtain guides from all 50 states and Canada, (b) develop a rationale for the guide, (c) develop a framework for writing the guide, and (d) operationalize an extensive advisory committee consisting of teachers, administrators, teacher educators, leaders in industry, and DAVTE staff. More than forty people participated on this committee. They were divided into two groups—one met in the northern part of the state and the other in Central Illinois. These groups advocated a major shift from the traditional "industrial" curriculum base to much more of a "technology" thrust.

1983: Dr. Franzie L. Loepp made a presentation at Chicago State University's mini-convention; Dr. Loepp came to Chicago and trained a local cadre of fifteen staff members—seven central office staff and eight teachers.

1983-84: Five of the cadre trained or provided general knowledge to 125 teachers.

1984-85: Local teachers received production technology training, communication training and transportation training via workshops.

1987-89: Follow-up groups met for production, communication, transportation, and energy utilization training. Large and small group meetings were employed for this.

Personnel Development Is The Key

One of the major functions of the central office during the early stage was to seek and select dynamic, enthusiastic teachers to become the trainers for their colleagues. In many cases, these persons also

became the curriculum writers. As the initial training and follow-up classes were completed, leaders in various disciplines began to emerge. The major staff development necessary to accommodate the large groups of teachers involved was based on the phase-in process shown in Figure 9-2.

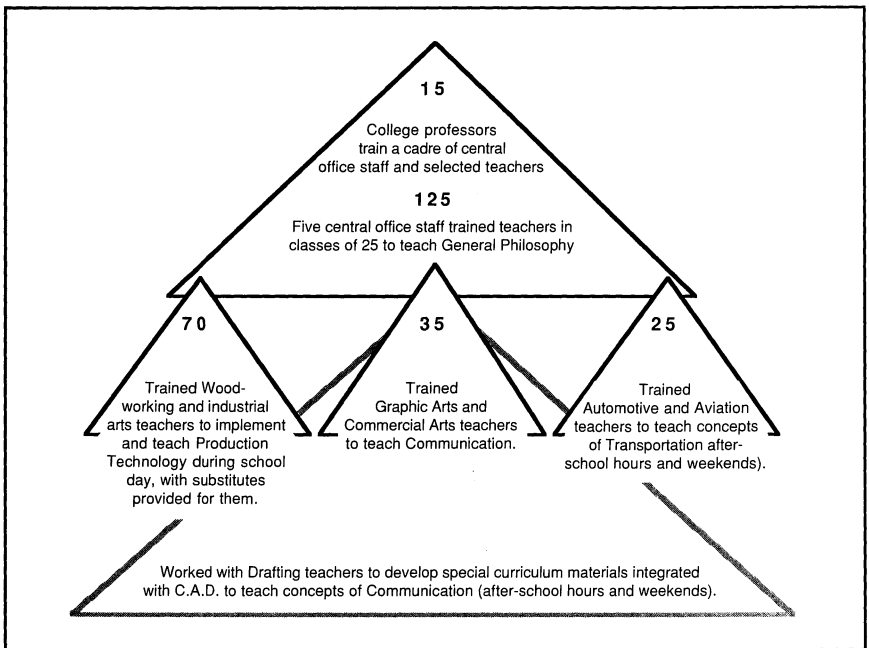


Figure 9-2. Staff development overview.³

Teachers involved in retraining also worked on curriculum development, including the writing and dissemination of curriculum guides. The guides were distributed to all teachers to field test. Teachers were encouraged to provide feedback for revisions, before full adoption and usage.

³The numbers in each triangle represent the numbers of teachers involved in each activity.

To maintain the momentum and quality of the new curriculum, it became necessary to set up a system of networks. Just as communication is important to a long-lasting marriage, networks are vital to a progressive curriculum. Examples of the network activities Chicago initiated are:

- mini-conventions (with new technologies on display for all technology education instructors),
- exhibits set up in schools, with varied categories to reflect changes in curriculum,
- section meetings, and
- school meetings, central office meetings, business and industrial site meetings.

District Support Activities

In retrospect, the support activities of central-office personnel can be classified as follows:

Budgetary or monetary: Providing consumable supplies, equipment, furniture, textbooks, instructional materials, repair and maintenance, purchasing procedures, budget preparation.

Professional growth: Providing curriculum development, university courses, workshops, conferences, conventions, professional organizations, inservices, circulation of published materials, foundations.

Follow-up: On-site visitations, resource lists and materials, telephone responses, letters, organization of networking, business and industrial contacts, legislation, student organization, newsletters, facility layout, purchasing advice and recommendations, current literature.

Without the interest, support, and enthusiasm of dedicated, professional educators, implementation would be stymied. Happily, these support systems have brought the program successfully beyond that stage.

Teachers now provide valuable input in the preparation of long-range objectives to keep the curriculum fresh and viable, because they are cognizant of the need to do so. With the myriad of technological advances, and the increased rate of development of other technologies, they know the need to move rapidly just to keep pace. The faculty members are ever-cautious of falling into the old thought patterns relative to industrial arts education which prevailed for decades, and

know that they can no longer teach the same way, or do the same things, that "shop" teachers did.

Technology has strongly influenced the course of history and the nature of human society, and it continues to do so. The great revolutions in agriculture, for example, have probably had more influence on how people live than political revolutions; changes in sanitation and preventive medicine have contributed to the population explosion (and its control); bows and arrows, gun powder, and nuclear explosives have in their turn changed how war is waged, and the microprocessor is changing how people write, compute, bank, operate businesses, conduct research, and communicate with one another. Technology is largely responsible for such large-scale changes as the increased urbanization of society and the dramatically growing economic independence of communities world wide (AAAS, 1989).

SUMMARY

In summarizing the implementation of support activities for technology education programs, on-going questions seem to bombard those who seek truth and reality. First, in dealing with the concept of technological literacy, is the gap—between the futuristic leaders of our profession and what our teachers are actually prepared to teach—too great? Do our profession's "visionary thinkers" realize that the majority of programs within our profession are still traditional in scope and content? Can the reality of the technological society housing education ever be adequately addressed in the schools? How will our technology teacher educators get prepared to train technology teachers? How do we get our supervisors, teachers, and teacher educators to **think globally and act locally**? Supervisors must, with greater fervor, develop a greater understanding about what technology is and what technology education shall be (Hughes, 1989). Perhaps the following quote from the French author Apollinaire needs to parallel reality for many supervisors as we work to lead teachers toward technology:

"Come to the edge," he said.

They said, "We are afraid."

"Come to the edge," he said.

They came.

He pushed them...and they flew.

Support Activities for Implementing Technology Education Programs

Thus for very obvious reasons supervisors continue to work diligently, persistently, and tirelessly to meet those challenges which will ultimately and unequivocally impact our society, culture, and environment in the 21st Century. They believe that technology education is a visionary curriculum and is the "New Basic" for the 21st Century curriculum. Technology education, through its process, provides essential elements and experiences to develop the "whole student." It addresses the economic, social, environmental, and ethical concerns involved in contemporary life. By providing "technological literacy," technology education prepares students—male and female, academic and non-academic—to function as knowledgeable and productive citizens in our increasingly technological world. Obviously, it plays an essential and highly valuable role in the total education curriculum. The transformation to technology education and the pursuit of a technologically literate populace are of extreme significance as our profession addresses the needs of our future society.

CHAPTER TEN

THE CHALLENGE FOR TECHNOLOGY TEACHER EDUCATION PROGRAMS

by
Larry Hatch¹
Ronald Jones²

Is the glass half full or half empty? It is easy to be negative. On the one hand, many things have changed since 1982. Our transportation, communication, and production systems have become even more complex. In sharp contrast, however, the curriculum delivered by our schools has not changed anywhere near as much. To be sure, technology educators are mobilizing to address the problem. However, optimistically industrial arts/technology teachers account for only 2.2% of the teachers in the U.S. (*Digest of Education Statistics*, 1988) and they certainly do not reach all students. Leaders within the technology education field openly acknowledge that a large proportion of its teachers are still traditional industrial arts teachers. Further compounding the problem is the fact that increased high school graduation and college entrance requirements have reduced student opportunity to participate in technology education. The overall result is that changes in technology are out pacing even our most serious attempts to address technological literacy.

Positively, however, one can see some genuine progress. For example, many authors in this yearbook have documented our profession's moves to better address technology. Scarborough (chapter 3) began by pointing out many of the advances overseas; Bensen (chapter 6) highlighted new thinking among key educational associations; Daiber, Litherland and Thode (chapter 8) documented the presence of exemplary models in our schools; and Stacy and Tobin (chapter 9) did the same for state and local supervision. So, where does the truth lie?

¹Larry Hatch is Associate Professor, College of Technology, Bowling Green State University, Bowling Green, Ohio.

²Ronald Jones is Director of Teacher Education, Department of Industrial Technology, University of North Texas, Denton, Texas.

Starr (1988) documents the U.S. as being in an ever weakening global position, from both educational and economic perspectives. He reports on the demand for an increasingly technical workforce and contrasts this with high school students ill equipped for either college or the workforce. America must demand an educational system that equips its youth to face the significant demands and social implications of its own technology. The educational system has been negligent in failing to provide students with a basic appreciation of the risks and benefits of their technological culture. Americans need an educational system that will develop citizens who are productive, informed, and aware of the cultural changes around them. Obviously this requires capable and willing teachers. In turn, this demands effective teacher education. Consequently, technology teacher education must face up to the challenge of building an effective system for equipping the technology teachers of the future.

The public readily admits that our education system needs help. A decade of studies have documented that the U.S. is in an ever weakening global position, from both educational and economic perspectives. The effects of a malfunctioning education system are clearly evident in the economic sector that is out-paced daily in innovation, production, and marketing by countries such as Japan and Germany. America has an educational system that is not equipping its youth to face the significant demands and social implications of its own technology.

GROWING DIVERSITY IN TEACHER PREPARATION

During the 1960s and into the 1970s it was characteristic of industrial education programs to have the majority of students enrolled in teacher education. To a large degree teacher educators taught **technical** content and, not surprisingly, they frequently incorporated instruction about key aspect of teaching methodology within their technical courses. Placement of student teachers was easy because many good role models were to be found in our schools' woods, metals, or drafting classes. Although numerous model curriculum thrusts were proposed during this time, for many institutions this was a period of relative stability.

As the institutions approached the 1990s a number of characteristics of teacher preparation programs had changed. In most cases the number of students enrolled in non-teaching options far outnumber teaching majors. As a result, it became common to have engineers or

non-teacher educators teaching technical content. The ensuing program emphasis shift reduced the number of model teacher education programs. Increasingly teacher candidates came from two-year technical programs. This had the effect of reducing their time at the four year institution. Compounding the preceding, and while this was occurring, teacher education reform thrusts such as the Holmes Group, recommended dramatic changes to the basic structure of teacher preparation. Together, these forces, coupled with academe's ever-present shortage of funding, created a paucity of effective teacher education program models.

Previously, in the 1960s for example, it would have been a simple matter to respond to these forces by developing a uniform plan to equip students with the essentials of technological literacy. Then, the departmental structures, course offerings, and sequences were much more uniform. In the current decade, however, suggestions must be flexible enough to be feasible in very diverse university settings.

Consequently, this chapter seeks to describe selected key components and their configuration rather than to create a recipe for infusing technological literacy. This framework should work interactively with the model of technological literacy presented in chapter 7 to guide practitioners towards more effective technology teacher education.

KNOWLEDGE BASES IN TEACHER EDUCATION

While the scope and sequence of education programs varies, certain components in the preparation of technology educators appear to be consistent. Wilson and Moore (1989-1990) developed a generic model for teacher education institutions, based on the research related to teaching functions and domains of knowledge. Figure 10-1 contains a graphic representation adapted from their model. It depicts four key domains which will be used to frame this chapter.

This general model can be useful in deciding where and how technology teacher education preparation must address and focus on technological literacy. It illustrates the generic knowledge bases in teacher education and their purpose in relationship to the functions of a teacher. Providing future teachers with practical, attitudinal and intellectual tools to develop the technological literacy of their charges means that technologically-relevant studies must be incorporated into each domain of the curriculum.

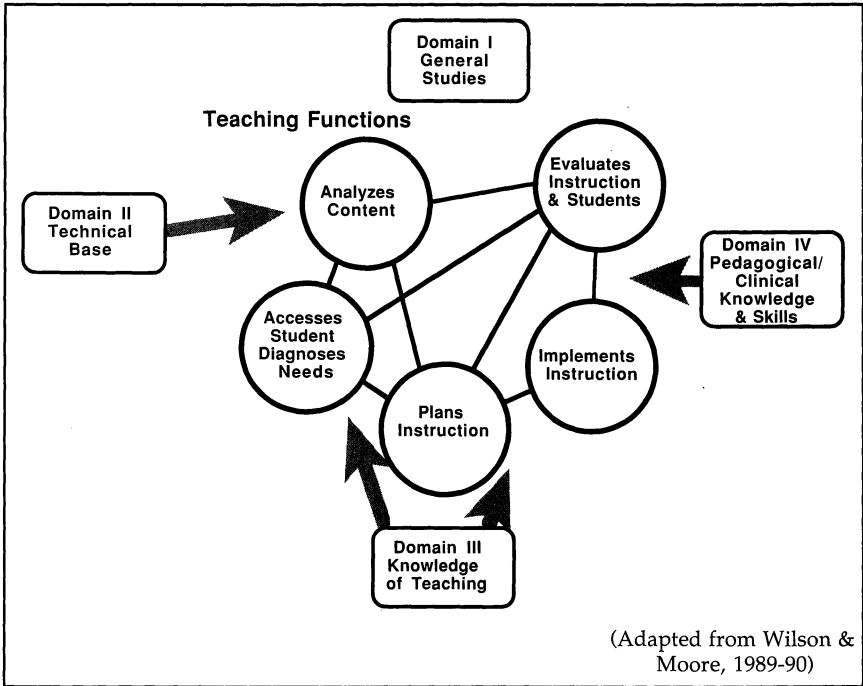


Figure 10-1. Technology teacher preparation knowledge domains.

Domain I: General Studies

In a changing world, a broad background is essential for teachers to become capable of transmitting technological literacy. Technology has transformed medicine with breakthroughs in heart replacements and surgical techniques. It has opened new doors in science that range from the destructive power of weapons to the wonder of space travel. Technology has raised issues in the legal system and with religious institutions regarding the very essence of life. Consequently, teachers attempting to develop technological literacy must be aware, in the broadest sense, of how technology affects consumers, occupations, the family, and society in general. It is essential these teachers be equipped with a sound general studies experience during their early preparatory time. Future teachers must necessarily have an understanding of the current technological issues facing our global community and their roots in anthropology, sociology, the arts and the humanities. In a world of change, a broad background is essential to preparing teachers capable of transmitting technological literacy.

Another related challenge is preparing technology teachers capable of infusing math-, science-, English-, and social studies-related learning experiences into their technology-based activities. In today's crowded and hard-pressed curriculum, technology teachers will be expected to become integrators. Part of the reason for this is to legitimize their (and technology education's) existence to decision-makers who only see threats of accountability for basic skills looming on their horizons. To head off such pressures, teachers must know the fundamentals about applications of math and science. While they may not need to understand higher levels of calculus, they should possess a substantial capability with mathematics (algebra and geometry) and at least be knowledgeable of how statistics are used in every day life. Similarly, teacher candidates must also have a basic understanding of the physical, biological, and chemical fundamentals that control how technology functions.

Finally, and perhaps the most critical of the general studies domain's dimensions, is the challenge of communication. Teacher candidates must be able to communicate at a very high level. They should write clear and coherent paragraphs. Legibility is also important. They should be exceptionally capable with the spoken language, and they should have a classroom and interpersonal presence that engenders confidence and trust.

Domain II: The Technical Base

The bulk of the "substance" delivered by technology education is obviously technology. Because of the importance that teacher education programs prepare candidates with substantial mastery of technology, its treatment here will be in some depth. Four sections are used to highlight important course suggestions for the development of the technological competence of prospective technology education teachers. These sections deal with, in order, systems courses, "tools for tomorrow" courses, advanced technical courses and "technology in society" courses.

The identification of appropriate technical content for students is at the heart of the redesign task facing many technology teacher educators. While it is often suggested that a fifth year is needed to be able to cover the technical content, it is not likely that this will solve the dilemmas of preparation depth or status of the teaching profession. In actuality, there always has been too much technical content to learn in a four-year program. Technology is so broad a discipline, and it is

advancing at such a fast pace, that one cannot even hope to understand or study it all, regardless of an additional year or two of study. Frankly, even a lifetime of additional preparation would not be sufficient to encompass definitively all of technology. In short, this is a false goal.

Consequently, it is time to recognize that pre-service programs simply cannot provide students with enough technical content to prepare them for a lifetime of teaching. However, with careful planning, students can develop mastery of the fundamental framework underlying technology and the basic skills needed to apply it. This should also engender a sense of confidence with which candidates can approach future changes. Simply put, if we expect teacher education graduates to help advance the technological literacy of their charges, teachers must themselves be technologically literate—and that at a high level! Future teachers must achieve a high level of technological literacy, in the practical, civic, and cultural domains, with sufficient depth to push them out of the nest and into the uncharted classrooms of technology education and the future.

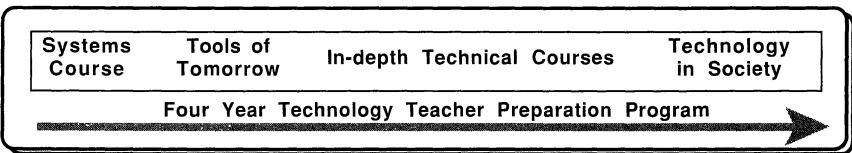


Figure 10-2. A suggested framework for a four-year technology teacher preparation program.

Technological Systems Course

It is sound practice to begin an educational experience with advance organizers that provide a framework for understanding a content area. This is particularly important with content areas that push the frontiers of human knowledge. All core courses should therefore, include a thorough look at technological systems through both macro and micro lenses and emphasis must be placed on the systems model. While there are a number of such systems models almost all of them represent useful ways of understanding technology. Technological systems can be analyzed to identify their component parts, effects of change can be monitored through feedback, controls can be adjusted and products improved.

In their technical core, students must be able to develop experience in analyzing both complex systems (e.g., a manufacturing plant) and relatively simple systems (flashlights) as well as familiar (e.g., the automobile) and unfamiliar (e.g., a new bio-tech system) ones. With the intelligent use of systems theory as a powerful tool, students can learn how products are made, the functioning of a laser disc, how a skyscraper was constructed, or why any of the myriads of other technological artifacts function. The systems approach is therefore the basic building block for developing technological literacy.

The development of a conceptual understanding of technological systems must be started right at the beginning of the teacher preparation program. And, it must continue to be a significant theme in each subsequent technical course. Only through repeated use will teacher candidates gain confidence in the power of this analytical tool and their skills in using it. By the end of their preparation period, candidates will be able to cope with the inevitable technological changes that will take place in the years after their university phase ends.

Tools for Tomorrow

At the 1990 ITEA conference, representatives from the Delta County, Colorado school system presented a program describing a high school course entitled "Tools for Tomorrow." This course is one of the particularly critical courses in the technology education curriculum. In it, students learn how to use computer hardware and software, as well as other information technology tools, that they will encounter in the world they are about to enter. More specifically, students learn how:

- photographs are digitized
- voices can be included in electronic reports
- to simulate technological devices/systems
- data bases are used and developed
- electronic mail is sent and received
- to create presentation graphics
- to draw electronically
- computers can interface with other devices.

If high school students need this level of technological capability, the same must certainly be true for the technology teacher. Information gathering, design, audio and visual communication, as well as other learning support activities, must be incorporated in a "tools" type of course. These are skills essential to technological literacy. They are also skills that play an important role in maximizing the candidate's entire university experience.

Advanced Technical Courses

By mastering the two previously discussed building blocks, students will be well prepared to study the application of specific technologies to particular technological systems. For teachers in training the method of delivery for technical courses is perhaps as important as content. By now, candidates should have mastered a fundamental understanding of and capability with, a wide variety of technical processes, e.g., separating, combining, and forming. The practical goal of technological literacy is to have an ability to recognize, clarify, formulate and solve technical problems. Therefore the information presented can best be understood in light of solving technical problems. These problems might involve production, communication, or transportation systems. They all require that knowledge be applied together with practical skills in using available resources and with processes such as designing, developing prototypes, testing, measuring and controlling to name but a few. Through problem solving, students gain practical skills that should be transferable to unique problems they may find in the future. Research and experimentation and development experiences should compliment and extend the problem-solving ones as well.

The technologically literate teacher should also understand the management of technical resources in the production of a variety of technologies. Managing time, tools, capital and human resources in different settings are practical skills essential to the technologist.

To be fully capable in applying the systems model, teachers must be able to control technological systems. This requires that candidates understand digital electronics, fluid power, sensor technology, and concepts related to computer control. In the area of bio-technology new control mechanisms, i.e., those related to living organisms, must be studied. With controls and sensors, the teacher candidate becomes capable of creating entire technological subsystems with built-in feedback.

Finally, and of critical importance, is that technology education majors have a synthesis experience that requires them to integrate most of what they have mastered into a viable whole, i.e., to demonstrate technological literacy. Capstone experiences could serve to challenge advanced students to bring together their understanding of design, power, electronics, manufacturing, and communication into powerful and realistic experiences. For example, university students might take on an engineering design problem, solve a local technologi-

cal problem, develop a unique curriculum, or research new materials. In this way they should come to understand how different technologies work together. They will gain appreciation for the importance of management skills and applications of what they know. This type of experience must also allow for the advanced student to examine the ethics of technology. After developing a solid foundation of technical understandings and skill, it would be wise for teachers-in-training to inquire and reflect on the purpose of technology, the shifts it is causing and the needs for control of technological applications and growth.

Technology in Society

While courses with this title are finding their way into many university catalogues, considerable work remains to be accomplished in exposing teacher candidates to a comprehensive overview of technology in society. Such courses could be organized in a fashion similar to that of a recent Chicago Museum of Science and Industry exhibit. It used four themes, each centered on the concept of "world," i.e., the **living world**, the **material world** (non-living), the **physical world** (motion, power, work) and the **information world**. By studying each world students experience how to use its technology, research the context of its civic issues, and appreciate its technologies' risks and benefits of technology. A sample matrix of content addressed by such an approach is displayed in Figure 10-3.

World Perspective	Doing	Knowing About	Attitudes Toward
	Practical	Civic	Cultural
Living World	Human, Animal & Plant Resources	Genetic Engineering Global Warming	Agriculture & Medicine Renewable Energy
Material World	Material Removal & Transformation	Asbestos Dioxin	Construction & Manufacturing
Physical World	Simple & Complex Machines	Robotics	Transportation & Energy
Information World	Database Retrieval	Electronic Surveillance	Telecommunication Privacy

Figure 10-3. Sample content for core courses providing the basis for technological literacy .

One appropriate placement for a technology and society course might be toward the end of the advanced technical sequence and the teacher preparatory experience. Candidates would then be able to reflect on what they have learned to do in light of the civic and cultural impacts of technologies. The method of delivery for this dimension is critical, largely because its significant impact on subsequent affective outcomes. The exposure to issues in the civic dimensions of technological literacy must result in the development of teachers with the confidence, inclination and ability to understand key technological issues facing our society. Because it is so difficult to predict the new technological issues America may face, it is imperative that students learn a process by which they can become informed about them. Teachers in training must be able to gather information, weigh alternatives, and be prepared to discuss and live with the consequences of their decisions. Ethical issues must not be skirted; instead teacher candidates need to learn systematic ways of addressing them. Simply put, young professionals will not gain this type of understanding unless they are challenged with a methodology that includes critical thinking, decision making, technology assessment and problem solving.

The methods for delivering objectives in the cultural domain should focus on significant questions about technology. Students need to understand why the world is as it is, the role technology has played in the history and development of the human race, and how people have adapted to their environment through technology. They should be asking how technology develops, where it comes from and what drives it. This aspect of technology has been exceptionally and effectively illustrated in the televised *Connections* series by James Burke. He illustrated, in manifold ways, how technology evolves and he vividly demonstrated that every major technological system should be understood in the context of time. Teacher candidates should study and analyze technologies using time lines, historical simulations, futures research, trend extrapolations, and anthropological models among others.

Domain III: Knowledge of Teaching

Our teacher candidates must also master, as a result of our programming, the skills needed to perform the "teaching act." Given today's trends, it is likely that the transmission of much of the knowledge about teaching will require a joint effort between technology education and other departments such as curriculum and instruction ones. While many components of knowledge about teaching are generic, other top-

ics take on special significance in the technology classroom. For instance, physical handicaps create special challenges in a hands-on environment.

New kindergarten- through twelfth-grade curricula which have been specifically designed to enhance technological literacy are only now emerging. Teacher candidates will need to be able to evaluate textbooks and other curriculum materials to compare how objectives are determined and sequenced and to evolve new instructional strategies. For too long, teachers have been prepared to produce projects, when what is really needed are people who focus on developing the potential of students. Therefore, future teachers must address the curriculum's new objectives and be able to select appropriate activities from the widest possible array of instructional strategies, including problem solving, group work and simulation as well as the host of new, technology-delivered methodologies.

Domain IV: Pedagogical/Clinical Knowledge and Skills

The fourth and final teacher preparatory domain is crucial to the profession's overall success. Our teacher candidates need to be able to employ pedagogical and clinical capabilities to tailor the instruction received by each child. There are grounds for hope that this will occur more effectively in the future. For the first time, the United States Department of Education is funding technology education demonstration projects that hold promise for the upgrading of this area. Through this effort the profession should also be able to establish a national center for excellence in teaching technology education. A demonstration project that focuses on teaching could address a number of key issues facing the profession.

Technology teacher education programs are faced with the dilemma of preparing a new type of teacher with few, if any, role models. This does not imply there are no effective teachers in the field, but rather that there are not enough exemplary technology programs for students to use as a role model. Without question, the technology education profession would gain significantly by providing students with outstanding examples of teaching. In this age of telecommunication, the neophyte teacher should be taken into the classroom of the experienced master teacher for much of the field experience. Remote broadcasts, videos and laser discs hold great promise to provide powerful examples of excellent teaching.

The practice teaching component is obviously crucial. It would seem advantageous therefore for the profession to establish a national teaching center for excellence in teaching technology education. Such a center could network master teachers, curriculum innovators, and teacher educators. It could serve as a forum from which, using the linking pin approach, thousands could be trained and upgraded. It could be the place where research could be conducted to validate new methods of instruction, to assess new evaluation techniques, and to experiment with new concepts. This could be a place for new teachers to gain polish by observing experts in presentations, demonstrations, cooperative learning, and group instruction.

SUMMARY

To prescribe a path for teacher educators is, at best, a serious professional risk. However, we must continue to discuss, to provide forums for discourse, and to engage in dialogue if progress is to continue to move forward and upward; that is, to follow the growth pattern of technology. Although change is taking place in some teacher education programs, apparently not enough is happening or the wrong type of change is taking place in technology teacher education programs. This seems to be verified by the experience of programs attempting to meet the newly established Council on Technology Teacher Education (CTTE) and National Council for the Accreditation of Teacher Education (NCATE) accreditation standards. As of this writing, almost all of the first twenty-six programs that were reviewed failed to meet one or more portions of the standards. Yet the profession continues to expound on the importance of "cleaning up" our act. Addressing the four domains highlighted in this chapter will certainly be a positive step—particularly if the task is approached without the preconceptions derived from "historical baggage."

Technological literacy has been discussed by the profession for many years. Obviously, any attempt to prescribe a path for developing technological literacy is risky. However, it is the authors' hope that this chapter will provide yet another viewpoint to generate opportunities for discussion, discourse, and dialogue, and, above all, the action that is so sorely needed!

CHAPTER ELEVEN

TECHNOLOGICAL LITERACY: THE EVOLVING PARADIGM

by
Paul W. DeVore¹

ENTERING THE 21ST CENTURY

As they entered the 21st Century, the members of the technology education profession were overwhelmed by the enormity of the vast changes in the technological base of society and their implications for technology education. They recognized that the changes brought about by continual change in the technological base of society were almost beyond comprehension by any one person. The technical base had become more complex. Significant social and human impact resulted from the expanding use throughout the world of all forms of high-energy technical means in transportation; in the transformation of the Earth's resources; and in private, corporate and governmental use of high speed communication and information devices and systems. The ever increasing use of more complex, powerful, and energy-intensive technical means brought about consequences that many had predicted in the latter decades of the 20th Century.

Local and worldwide leaders in the field of technology education had realized that they face a dilemma, given the heritage of the field. They were correct. There was a forced reassessment of the very essence of technology education. There was a search for meaning...a search for purpose...a search for reality. They, and others—educators, lay public, government leaders and corporate officials—recognized that there was a critical need for certain levels and types of technological literacy among citizens. However, they also recognized there was considerable confusion about technological literacy and how to proceed to investigate it, establish direction and attain it. Upon examination of their

¹Paul W. DeVore is Professor in the Technology Education Program, College of Human Resources and Education, West Virginia University, Morgantown, West Virginia.

assumptions they discovered that some were false. On examination the belief, that it was possible to infer or determine what technological literacy was by looking at what technology education was seeking to accomplish, was found to be false. This exposed one of the primary flaws of the profession; namely, **the belief that the means for providing technological literacy—Technology Education—could also provide the definition of the end.**

TRANSITIONING TO A NEW REALITY

As so often happens, the profession was caught in a paradigm shift, a shift that began in the 1960s. This shift was occurring worldwide and was brought about largely by the creation and use of new and more powerful technical means. Gradually people began to realize that there were limits to the carrying capacity of the Earth and that there was a need for the creation of alternative technical means, means that were more compatible with the natural environment. The ability to see the Earth from outer space and to observe the destructive results of human activities brought about a change in thinking and a new vision of reality. The values in which the profession had grounded its action were called into question. On entering the 21st Century, citizens and educators found that technological literacy was situated in a larger context than those defined by international competitiveness and career or vocational preparation. The heritage of the field of technology education clouded the issue for many. The question that best probed the essence of the issue was: "What knowledge and know-how is of most worth for the citizens of the Spaceship Earth?" The vision that emerged came about from an evolving belief that humanity, as the crew of Spaceship Earth, had a moral responsibility to manage and nurture the Spaceship to assure the continuation and improvement of life.

Transitioning to the new reality was not accomplished without difficulty. The tradition of technology education was a long one, beginning with Swedish Sloyd and evolving to manual training, manual arts, industrial arts, industrial technology, and technology education. The content focus during the evolution from one education era to another included an occupation focus where the trades of cabinetmaker, woodworker, and welder were taught; a product focus where radio, television, and automobile servicing were taught; a skill focus where job skills in drafting, leatherworking, and forging, among others, were

taught; and a systems orientation that focused on the basic needs of society—food, clothing, shelter, material goods, communication, information, energy, power, transportation, and the problems and issues associated with the creation of society and the design of technical means in meeting these needs. Historically the profession found, on examination, that there was always a lag; that the needs of society were always forcing the field to change. The field of education, rather than providing leadership for the future, often became part of the problem in a changing society. There was a crisis in leadership within technology education and in the education community in general.

THE QUESTION OF CURRICULUM MODELS

During the late 1980s there was considerable activity in the education community concerning scientific, mathematical, and technological literacy. Numerous members of the technology education community were involved. Attempts were made to create models to explain technological literacy as had been done for the field of technology education in previous years. An examination of the models proposed indicated considerable similarity. Upon close examination, however, there seemed to be a lack of a critical element. The models did not seem to be able to communicate the essence of technological literacy. Nor did the models of technological literacy provide a vision that was clear and succinct; a vision that had the potential of communicating with others and which others could follow. Some models confused rather than clarified. There was a tendency to include the accumulation of the content of the field of technology education without first responding to the questions: "What is technological literacy?" and "Why is technological literacy important?" Thus, the models were not grounded within, nor compatible, with either the current cultural world view—the industrial scientific mechanistic paradigm—nor the emerging world view, the new environmental paradigm with a focus on living systems and bio-regionalism.

By the beginning of the 21st Century the profession began to realize that it would be necessary to clarify the essence of the mission of technology education and to search for answers to the questions: "What is technological literacy?" and "How does technology education contribute to technological literacy?" The members decided that any models developed would need to have the same characteristics as good

mission and goal statements; simple, not complex; specific, yet comprehensive; and inclusive, yet understandable. In addition, the leaders of the profession initiated a series of discussions to establish criteria for the development of taxonomies and structures for the field of study and for their work on technological literacy. During deliberations it was agreed that the following guiding principles would serve as criteria for the selection of components for their models:

- Categories or clusters must be mutually exclusive and established in a hierarchical order...each larger unit a combination of subgroups.
- Each category, cluster, or subgroup would be identified by a word or phrase that specifically limits the category, is non-transient and permits additions to the structure as new knowledge and information warrant.
- The number of mutually exclusive groups or categories or groups would be relatively small in number.
- Categories, clusters, or subgroups would be established by an identifiable and agreed-upon universal concept inherent to the content of the category.
- Models would be logically developed and have internal consistency.
- Models would evidence external stability and have the potential for internal flexibility and adaptability to change.
- Models would be inclusive in that they would be international in scope, yet valid at the local level.
- The categories would be of the external world and not simply categories of the contents of first-person experiences.
- The structure of a model would evidence and inform about the internal relations existing between and among the elements.
- The structure of a model would vary according to the subject being investigated and range from extremely logical and homogeneous categories to vague, ambiguous, heterogeneous, and difficult-to-define relations among the elements
- Insight into the behavior of the phenomenon being modeled would be enhanced for those using the model.

In their investigations of the problems and issues of model building, the members of the profession discovered a critical factor; namely, that in certain cases it was possible that the subject being investigated

could be analyzed in different ways. Thus, it was possible to construct totally different models, none of which seemed to have a relation to the other, but each model providing the user with an equivalent explanation of the whole. This, of course, did not mean that just any model would do. The best model would be the model that best explained the essence of the phenomenon in question. This meant that prior to model development it would be necessary to establish the cultural paradigm in which the model would be grounded. The tenets of the cultural paradigm would guide the construction of the model and provide the criteria for evaluating the model for external and logical consistency.

THE DESIGN DECADE

The members of the profession, after many years of debate, initiated in 2001 a design decade for the purpose of meeting their challenge and responsibility as technology educators. They did so after realizing from their deliberations that the problems and crises the society and their profession were facing, were ones of perception and not capability. They found in their investigations that their mission was noble; that it was a mission that had to do with improving the human condition. By the end of the 20th Century it had become apparent that those who had concluded in the '90s that most of the technical problems had been solved and that the issue of technological literacy was a moot point were wrong. The fact was that the shift in the cultural paradigm toward the new environmental ethic required, for the most part, a redesign of most of the technical means and infrastructure of society. What had been perceived as progress in the latter part of the 20th Century was discovered to be an illusion. It was a form of progress that was not sustainable. It was a progress based on a technological system that was built on the belief that growth was positive and could be sustained. However, it became apparent that the living Earth had limits; and in report after report and forum after forum in the latter years of the 20th Century, the evidence accumulated. The result was that humankind had to reassess its basic assumptions about the creation and use of technical means and initiate programs of education to prepare individuals to create new technological systems compatible with the biosystem on which all life depends.

CRITICAL DISTANCE: A FOUNDATION FOR CHANGE

By the end of the 20th Century it had become obvious that there was need to reconceptualize the direction of the field of technology education particularly with respect to the goal of technological literacy. The entire context and rationale for the field of study had been changed by the evolution of a new cultural paradigm or world view. What was already a complex, multifaceted field of endeavor became more so.

Members of the profession revisited the past efforts of the profession, including the content and structure models of the field. They discovered during this examination that the evolution of the field was established on a valid philosophical foundation and that technology was gradually being accepted as a science. The focus that emerged in the latter part of the 20th Century emphasized the systematic study of the creation, utilization, and behavior of adaptive systems (tools, machines, materials, techniques, and technical means) and **the behavior of these elements and systems in relation to humans, their societies, and the life-giving and life-sustaining environment.** The recognition of the relation of technological endeavors to the condition of the natural and life-giving natural systems was a key shift in perception. The new focus provided a structure for meeting the challenges of the shifting cultural paradigm. What was missing was the design and implementation of quality programs of instruction in teacher education programs and the classrooms of the world.

The cultural evolution that was taking place in the world and forcing a reexamination of context and rationale for all institutions was brought about by the effect of individual actions in the use of technical means which became collective human actions. The aggregate effects of these collective human actions became more and more detrimental to human beings and destructive of society and the natural environment. It became imperative that those involved in the education of citizens for living, in democratic and other societies as well, address the issue of how to prepare citizens to act intelligently and responsibly in an increasingly complex technological world. It became clear that a society based on a high order of technical means altered the question with respect to error and failure. Failure in a complex, highly populated, technological society was of far greater consequence than failure in earlier eras. In earlier times, technical means were not as powerful nor potentially destructive of life and the natural environment, and dependency on multiple subsystems not as great. In earlier times if systems

were disturbed they returned to equilibrium in a relatively short period of time and damage to humans, society, and the environment was limited. The nuclear accidents, oil spills, and destruction of entire communities by technological change in industry provided too many examples to be ignored. Humans were clearly not in charge of their own destiny. The design of their technological system was flawed. Whereas in the past it was sufficient to know how to control single devices and elements of technological systems, the issue became one of understanding the behavior of technological systems as major components of social systems and the interrelation of the technological and social systems with the natural systems.

Technological Change

An examination of the past to gain critical distance and identify critical variables in the human experience brought forth the conclusion that technological change had been a constant in the civilization process. The difference in the latter part of the 20th Century and the early decades of the 21st Century was the pace and magnitude of the changes and the impact of technical means on the life-giving and life-sustaining environment. What seemed to be called for was a massive redesign of the technical systems of society.

The redesign process would require the evaluation of the primary enabling elements that have altered human potential throughout the civilization process. These include:

- a more stable food supply;
- new and better materials;
- alternative forms of energy;
- more efficient means of energy conversion;
- more efficient means to (a) collect, (b) store, (c) transmit, and (d) process information; and
- better means to control tools, machines, and technical systems.

A Growing Crisis

The technical means associated with each of the primary elements came into question during the latter part of the 20th Century and the early decades of the 21st Century. The nature of the technical means being used by an increasing population worldwide affected the natural environment to such an extent that all forms of life were threatened. Many species were becoming extinct and large sections of the Earth were becoming uninhabitable.

The actions of humans, using their highly complex and powerful technical means, had become a super malignancy on the planet. The problems were increasing at an alarming rate. There were continuing energy supply crises; the threat of global warming resulting from the increase in fossil fuel use and the decrease in the forests of the world; the growing shortage of water in much of the world that affected personal health, agriculture, industrial processes, energy conversion and the extraction and processing of resources; the collapse of the physical infrastructure—roads, bridges, railroads, water and sewage systems, dams, public buildings and energy conversion systems; deteriorating cities; problems of caring for the elderly, the issue of medical care costs and wellness versus sickness; racial conflict in most countries; the decline of the family; the shortage of potable water; crime of all sorts; the problems of privacy in a surveillance society where interactive media, voice analyzers, and all forms of recording devices existed; the increasing use of toxic chemicals, ozone depletion, and acid rain and the resulting destruction of forests and life in lakes.

Interestingly, the number, magnitude and seriousness of the problems increased at a time when there were more scientists, technologists, political scientists and other experts and specialists than ever before. The question of whether too many critical decisions had been left to narrowly prepared specialists emerged. This was the era when the world was becoming more technological, not less, and when there was a continual transition from a world of low entropy and orderliness to a state of high entropy and disorder. The mentality of the industrial era had been to produce, consume, and grow. The result was the creation of very inefficient and wasteful transformation and use processes with built-in inflation that only continued to increase as the population increased and the availability of resources diminished. The "grow at any price" mentality was called to question.

People were discovering there were limits to natural systems. They began to reassess the purpose of life on Earth. They became aware that humans were a part of a great tragedy in the making. They discovered that technical means alone could not solve their problems; that a succession of technical fixes had only enhanced the crises. They emerged from their introspection and reflection of the history of civilization with a new vision of life and living. They realized that the focus and content of their education system had to be redirected, primarily because even though their knowledge base had been changing, what

they had been pursuing had remained constant—the human factors of love, hope, happiness, and a meaningful life. Measured in human years, decades, generations, and lifetimes, it had been a long struggle. But measured in the time perspective of humanity and life on Earth, time took on a new dimension and the impact of humans was perceived as starkly more dramatic as noted by Myers (1984).

If we compress all of the 15 billion years of the evolution of the universe as we know it into a single 24-hour day, the Big Bang is over in less than a ten billionth of a second. Stable atoms form in about four seconds; but not for several hours, until early dawn, do stars and galaxies form. Our own solar system must wait for early evening, around 6 p.m. Life on Earth begins around 8 p.m., the first vertebrates crawl onto land at about 10:30 at night. Dinosaurs roam from 11:36 p.m. until four minutes to midnight. Our ancestors first walk upright with ten seconds to go. The Industrial Revolution and all our modern age occupy less than the last thousandth of a second. Yet, in this fraction of time the face of this planet has been changed almost as much as in all aeons before (Myers, 1984).

A Shift in Perception

Research, study, and reflection on the relation of humans to the long-term, with future-initiated computer models verified what some had only speculated about in the past. It became evident that it would be impossible to continue to model life on Earth after the industrial scientific model based on a mechanistic view of the world and the fragmented reductionist Cartesian perspective of the belief that the world and life could be understood as mechanical systems composed of separate parts. What was discovered was the intrinsic dynamic nature of physical reality; that the Earth, as it existed, was composed of a complex web of relationships where everything was related to everything else.

Thus, the future of humans on Earth became linked irreversibly throughout the world. More and more people came to realize they were visiting the tragedy-of-the-commons on the whole Earth. There was no escape. There was only one Earth. And the problems increased almost exponentially as each person and each nation attempted to maximize their position in terms of material wealth, to the detriment of others.

A New Form of Literacy

In the course of attempting to solve their problems, responsible people throughout the world discovered that freedom and liberty were directly related to responsible social and technical choices. They also became aware that the quality of their choices varied with the level of their knowledge and understanding of the behavior of their adaptive or technological systems in relation to the natural environment. It became apparent that the essence of evil was ignorance and that the problems associated with the destructive behavior of humans of the life-giving and life-sustaining environment was the result of general ignorance. In many sections of the world the cities were becoming inhabited by uncivilized urban barbarians.

A new form of literacy was called for; a technological literacy, but a technological literacy with a new focus. The new literacy focused on the choice and design of appropriate technical means based on the understanding of the relation of technical means to people, the social order, and the environment of the bioregion. It was a literacy that included values, conscience, and morality as cornerstones of decision making. The imperative of the new technological literacy became responsible intelligent action. The goal became one of accepting the consequences of actions and directing energy toward creating a sustainable quality human existence on Earth.

Where the focus had been on maximizing one's position in the short-term regardless of long-term consequences, the focus became one of promoting values and attitudes that enhanced the long-term benefits of human society as a whole and of all life on Earth. It was recognized that the civilizing process and literacy about technical systems and technical means were critical to the commonweal and that the development of a civilized, knowledgeable and responsible citizen takes time; that learning and mastery of knowledge and know-how and the development of values and attitudes were long-term efforts.

The leaders of the new technology education movement reiterated the belief of Thomas Jefferson on the need for intelligent citizens for the proper functioning of a democratic society. Jefferson said: "I know of no safe depository of the ultimate powers of the society but the people themselves; and if we think them not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion by education."

The focus of the new literacy was directed toward each individual as a member of the crew of the Spaceship Earth in keeping with Eric

Sevareid's analysis in the latter part of the 20th Century. Sevareid said he believed there were three problems that were new to history. One was the leap into space. Another was the creation of ultimate weapons. The third was the poisoning of the natural sources of life—the rivers, air, food. Sevareid pointed out that he did not believe any of the problems of humans would be solved in outer space. "I think," he said, "they're solved in inner space and inner man, on terra firma" (Kidder, 1987).

The new technological literacy was grounded in the belief that all citizens of the Earth must be educated so they can become adequate in meeting their responsibilities to the present and the future. This was a new context in which technological literacy was assessed in the 21st Century. The concern shifted from preparing "honest workmen" for the purpose of producing the goods and providing the services, to a concern about intelligent and responsible citizens, about ethics and morality and about the nature of technological choices and their impact on people, the environment, and the future of the biosphere. The new concern did not deny the importance of technical means to society. In fact, the new concern identified appropriate technical means as the **key** element in the design of a quality and sustainable human society. They rediscovered what Ayres had pointed out years before, namely, that the wealth of people was dependent on their technical means (Ayres, 1988). What Ayres neglected to point out was the necessity of designing and managing an appropriate technical means. There was a difference. The difference was that the appropriateness of technical means in the 21st Century was determined by the compatibility of the technical means to the natural systems of the Earth. The goal of the 21st Century was to design and manage technical means so they were a part of the natural cycles of the Earth and not apart from them.

This shift in the perspective of the purpose of technological endeavors and thus, the content and structure of education, related directly to a changing perception about the purpose of life and the meaning of being human. This new perception was the foundation of the changing world view and the change in perception about technological literacy.

TECHNOLOGICAL ILLITERACY

During the industrial scientific era, it was assumed that ordinary citizens were incompetent and their judgements faulty when the society faced questions about technical means. It was considered appropriate

to inform citizens about the issue in question, but the final decisions were to be left to the experts. This assumption was called into question during the latter part of the 1990s. There had been too many irreparable disasters when expert judgements were the final judgements. It was recognized that expert judgement sacrificed common sense to narrow and restricted experience. While there were barriers to the acceptance of new ideas and alternative ways of doing things, there was a certain dogma that permeated the conclusions of experts: for opinions and positions to be respected, they had to be anointed by those certified as experts.

The rejection of the "decisions-by-experts" approach to the choice and design of technical means meant that a broader base of technological understanding was required within the society of all people, including the experts. The fundamental truth of the new age was that it was not possible to select, design, operate appropriately, or control technical systems without a thorough knowledge and understanding of the behavior of the systems and their relation to humans, the social order and the natural environment. The design and operation of the new technical means required for transitioning to a sustainable and preferable future mandated a highly educated populace.

The leaders of country after country found that the intellectual capabilities and technological literacy of their citizens were central to being able to compete successfully in a global market, and to manage successfully the technical, social, and environmental interfaces within their communities and bioregions. The continued shift to new forms of sustainable technical means accelerated the rate of change. In general, the systems became more complex because of criteria requiring that they be designed to interrelate appropriately with other technical elements and the natural and social systems. Technical systems became more diverse. Diversity was required if the systems were to be compatible with the bio-region in which they were to function. This was particularly true in the design and redesign of the energy conversion, food production, and shelter elements of society.

The impact of technological illiteracy on the quality of life and the natural environment became far greater than at any time in recorded history. It became obvious that illiteracy in the technological realm affected communities and nations in many ways. Among the more critical were:

- An increasing drain on the resources of society by citizens unable to function effectively or contribute in a meaningful and productive way to their society;

- Loss of competitive economic potential by businesses and industries unable to obtain employees capable of functioning effectively in the highly complex, ever-changing, bio-technological environments;
- Lessening of the level of security of nations and communities during times of emergency, when citizens who should be able to contribute were unable to do so because of their lack of knowledge and know-how in the technologies; and
- The disfranchisement economically, as well as politically, of citizens from participating effectively in the governance and management of their communities and countries because of the increasing technological component of society.

Reassessing the Focus of Education

The relation between a quality society and the quality and appropriateness of the civilian technological base of society became better understood by community and national leaders. They discovered that along with political leadership a community or a nation must have a high quality of technological leadership. And that this technological leadership began with education—vision, values, attitudes, knowledge, know-how and commitment. The primary commitment of governments became one of educating their citizens, but with a different focus. The education systems of the past had muted the awareness of citizens of their ignorance of technical means and the relation of technical means to the human, social, and natural orders of the Earth. So too, did the education systems of the past mute citizen awareness and deny them access to knowledge and tools and limit their interest and awareness about the very systems that had the potential of enabling citizens to gain more control over their lives and participate in the creation of a more sustainable future.

Without access to tools and knowledge of technological systems, citizens were effectively losing control of their technical means. They were totally dependent on technical means, yet ignorant about them. In a similar vein, it mattered little how much a company or country invested in capital equipment; to take maximum advantage of the potential of the new technical means required that a high level of technological knowledge be spread broadly throughout the society if maximum advantage was to be derived and each community was to attain a high quality of life for its citizens.

The Perception of Technical Means

There was continual evolution in the way technical means were perceived. Most people in the 20th Century were aware that significant changes had taken place in society. Yet, most continued to perceive technical things in purely instrumental ways, as means to ends and oftentimes as ends only. This traditional view limited the possibility of gaining insight into the true nature of technical means. Martin Heidegger (Hood, 1968) and Jose Ortego y Gasset (1961) believed that the **being** of humankind and the nature and character of technical means were directly and intimately related in the ongoing process of life. Gasset stated that humans must act in order to be and that being supposes action (p. 116). Thus, technical means are not only a part of the structure that makes a quality society possible, they are also a part of a whole person's being. The creation and use of technical means have always provided new contexts in which humans have existed and had their being. Technical means have served as a mediating element as humans have interacted with their environment in the act of becoming. The greater the difference between one era and another, the greater the difference in the way humans have experienced the world and the way they perceive nature and the character of their created technical means.

Implied in this perception of the nature and character of technical means is the understanding that life is oriented primarily toward action, not contemplation and reflection only. Life is thinking **and** doing. To live is to be in the process of self creation, a process enhanced and made possible by the creation of technical means. The world encountered by humans depends on how they have created the world and how they have structured it cognitively. And how they create the world depends on what they encounter (Hood, 1968). Human endeavors in the creation and use of technical means are concerned with systems of knowing and doing. It is through these systems of knowing and doing that humans encounter and structure their world. Technological activities are fully within the human context and a natural part of being human. To be fully human is to be technologically literate.

Technological literacy had become increasingly critical in a democratic society—to the extent that technical means became increasingly embedded in the social, economic and political fabric of society. The questions that had been addressed the last several decades and were the critical questions of the day were: "How can the enhancement of

technological literacy be addressed in an increasingly complex technological world?" and "How shall the efforts be directed?"

The more the questions were investigated the more it became apparent that there were two primary areas. The first focused on the fundamental questions of all time; those that have to do with one's world view. One's answers to the questions were grounded in one's assumptions about life and living, about what it meant to be human, the natural environment, life on Earth, and the purpose of all life. It became imperative that formal education programs address the critical questions relating to life and living: "Who are we?"..."Why are we here?"..."Where are we going?" These were the essential questions. Responses to these questions provided the grounding for a valid formal education program of society. Secondly, it became imperative that the equation of technological choice and social and environmental consequences be addressed. Rather than accept as a given the continual indiscriminate infusion of technical means into society, the equation was reordered. Whether a new technical means was introduced became a matter of whether there was a valid social need related to an agreed-upon social purpose and whether the new means would be compatible with the natural environment.

What Learning Is of Most Worth?

The question of what learning is of most worth was revisited many times the last several decades. There was always the debate within the establishment of education of the relative merit of career and vocational education and academic education. The limits of the traditional approach to each were identified early in the 21st Century. It was discovered that—given the new information and knowledge about the biosystem, life, and the characteristics of technical means—for the most part, the wrong questions were being asked. The new question focused on the design of a system of education for the preparation of intelligent responsible citizens for life in a complex, interdependent, natural world. The goal was to identify those constants related to knowing and doing in the technologies and other fields that would be necessary and required of each citizen. There was a consensus that Netzer (1982) was correct in his Rule of Irretrievable Loss.

Students should be taught on a compulsory or universal basis only those things that large numbers of them will never learn unless exposed to the material at the stage in the education process in question, and which it is important that most people passing through that stage do learn (Netzer, 1982).

With respect to technological literacy there were many investigations and much discussion at forums throughout the country where answers to the question, "What should be universal and compulsory in the study of technology?," were pursued.

Those investigating the question of "What should be universal and compulsory in the study of technology?" found three areas to be particularly meaningful. These were technology and progress, technology and environment, and technology and ethics.

TECHNOLOGY AND PROGRESS

A number of individuals pursued research related to the role and function of technical means in society. Some surprising conclusions were reached. Robert M. Solow, 1987 recipient of the Nobel Prize for Theory of Economic Growth, proposed as early as 1957 that technical innovation and invention play **the** key role in economic growth. In a paper published in 1988, Robert U. Ayres reviewed the research on economic growth and concluded that economic growth could only be explained by introducing the notion of technological progress. The wealth that existed in society originated from technological innovations those societies that enhanced the possibility of technology through appropriate public policies, and cultivated within the population knowledge and understanding of the creation and use of technical means, were the more developed societies, with higher standards of living (Ayres, 1988).

Ayres believed that while wealth had "material aspects," wealth "was essentially a form of condensed useful information or knowledge." Thus, Ayres proposed that the ultimate origin of wealth was the human mind; the mind creates and designs new technical means and is prepared to operate, manage, maintain, and redesign technical means. With the identification of technical means as a key variable in the success of social systems, it became obvious that greater emphasis would be required within the system of education or the study of technology as well as research on identifying the determinants of invention, innovation, and the diffusion and adoption of technical means.

TECHNOLOGY AND ENVIRONMENT

In the latter part of the 20th Century there were two central factors that seemed to be directing a shift in the values and beliefs of Western

Society. One concerned the question of what it means to be truly human. Questions of freedom, responsibility, and intelligent action and behavior were pursued. The second theme that emerged from the grass roots of society centered on ecological factors and the realization that the quality and prospect of human life were linked directly to the quality of the natural environment. Questions of the relation of technical means to the biosystems and the responsibility of humans to the natural environment were investigated. The emergence of these two closely related factors formed a core for discussion of the meaning of cultural and technological literacy. As in the past, there was considerable confusion. There already existed many views of what constituted technological literacy. Each view was grounded in a specific paradigm, whether articulated or not. Most people holding views about technological literacy had never articulated the paradigm in which their view of technological literacy was based. Thus, there was considerable confusion and conflict. The confusion and conflict became more intense as the new paradigm emerged.

The promises of a technological way of life based on continued growth and development had been a part of the vision of the future for many years. The tenet of the prevailing cultural paradigm that guided this thinking was that continued development and cumulative growth would solve the ills of humanity. For a while this seemed to be true. The technical systems that had been developed did contribute to the improvement of the material quality of life, particularly in the Western World. However, as the systems became ubiquitous, larger and more complex, evidence emerged that there were critical flaws. Early warnings appeared in the energy conversion systems; nutrition and health; food production and distribution; land use policies; population increases; loss of arable land through destructive agriculture and resource management practices; and the increase in the deterioration of the Earth's biological systems, including the lessening of the diversity of the gene pool of life.

There was a stark realization that humans inhabited a living finite planet where there were limits to fossil fuels, natural fresh water, food productive arable land, habitable environments, the waste-absorbing capacity of the natural environment and the resilience of the life-support ecosystems of the living Earth. It became evident that the choice and use of technical means played a critical and determining role in the quality of the environment and the potential of developing sustainable human communities on Earth. The result was a shifting of perception about the importance of the relation of technical means to

biosystems and the long-term quality of human life. The concept of **sustainable development** became recognized as the oxymoron it was. People found that their perception of violence also changed. Where it was once believed that the destruction of the natural environment was development, the new view perceived this act as violence.

TECHNOLOGY AND ETHICS

Paradigm Shifts

Historically, the collapse of civilizations, bureaucratic orders, disciplines, and social orders has related to an incompatibility between the predominating mode of behavior and the evolving social or environmental context. When a large number of people within a society become aware of the seriousness of social or environmental problems, movements are initiated to seek alternative social and technological solutions. The new directions are guided by the necessity of meeting crises; crises which force a reexamination of beliefs, values and modes of behavior. When the movement to meet a perceived crisis reaches a critical mass, there is a paradigm shift. In the latter part of the 20th Century such a shift was occurring. A new paradigm was emerging. This evolving paradigm forced the field of technology education to reexamine its role and mission and the many geometric models proposed for the determination of content and structure. With the emergence of the new paradigm, there was a significant increase in the physical and intellectual energy in the field of technology education. The numbers of practitioners involved was fewer, but the accomplishments were more significant. They rediscovered what many had found before; that they could not include technological literacy as a part of their mission if the paradigm in which they were functioning was not well understood. In essence, they had to know and understand the context in which they were working.

The Industrial-Scientific Paradigm

The paradigm that was evolving was being driven primarily by concerns for the environment and the sustainability of life on Earth. The predominant world view in the West had been based on an industrial, capitalistic paradigm. Those working from this belief and value system perceived nature as a mechanistic system that could be understood by

analyzing the individual components. The belief was that nature should be controlled and used for the benefit of humans and that only minor adjustments would be necessary in the system to protect the ecosystem from harm (Drengson, 1983, p. 63). When tested against the criteria of sustainability, this perception was found to be lacking. The evidence continued to mount documenting extensive, and at times irreversible, damage to an ecosystem that nourished and sustained life. The shift that took place was from one that perceived life from a purely instrumental view to one that perceived **all life** as having intrinsic worth. It was a true pro-life perspective.

It was a difficult change for many in the profession and in society in general. Many opted toward directing their efforts to moderating the dysfunctions and destructive outcomes of the utilization of unappropriated technical means with the hope they could return to the good old days of the past. The results were unsatisfactory. Attempts at patchwork reform did not work. It became evident it would not be possible to continue into the future using the industrial-capitalistic model.

E.F. Schumacher addressed the question of "Why should the industrial society fail?" He responded to the question by noting that by following the industrial model humans had: (1) disrupted organic relationships; (2) rapidly depleted the earth's nonrenewable resources and scarce minerals—mainly fuels and metals; (3) degraded moral and intellectual qualities while further developing a highly complicated way of life; and (4) bred a climate of violence—a violence against nature that could at any moment turn into violence against one's fellow men (Schumacher, 1979).

The GAIA Hypothesis

The reconceptualization of the world view was influenced by the contributions of many individuals. They realized that the mechanistic world view and the fragmented reductionist Cartesian-Newtonian perspective, which proposed that the natural world and humans could be understood as mechanical systems composed of separate parts, might be in gross error. Two individuals who made a significant difference in our thinking about the world in which we lived and the technological systems we had put in place were James E. Lovelock and Dr. Lynn Margulis. Their work provided a base for establishing an alternative view of the Earth and called into question the mechanistic, compartmentalized view of the world. Their investigations concluded that the Earth was a living, self-regulating system. They called this perspective of the Earth the GAIA Hypothesis (Margulis & Lovelock, 1975).

A new awareness and new concepts emerged from this hypothesis. One of the concepts was bio-regionalism, a grass roots movement concerned with social and ecological sustainability. This concept was part of the emerging paradigm. The prefix "bio" places the emphasis on life. A bio-region is, therefore, a life-territory, a place defined by its life forms, its topography and its biota, rather than by human technological creations. It is a region governed by nature, not legislature (Sale, 1985). The concept of bioregion dictates that the nature of the technical means of the world would be more diverse, not less, if they were to be compatible with the unique environments of each bio-region.

Human Perceptions

The shift in human perceptions about the Earth and the relation of humans to the environment came about as the result of several primary factors. These were: (1) the recognition of the impact of the cumulative dysfunction of the dominant world-view of industrial capitalism; (2) the concern for the long-term effects of the policies of the industrial capitalistic view on the quality of life of humans throughout the Earth; (3) the growing recognition that the quality of human life was not solely dependent on higher and higher levels of material existence; (4) the changing perception of the relation of human life to other life on Earth; (5) the recognition that the Earth is a living self-regulating system and (6) the emergence of the bio-regional movement as a response to the challenge of creating and sustaining quality life on Earth.

LITERACY AND THE NEW AWARENESS

The awareness of how complex and interrelated the natural and created worlds really were impacted significantly on education, particularly technology education. The faith of technology education professionals was severely shaken. Their curriculum models had been based on the dominant industrial scientific world view, a view with basic tenets that had now been called to question. A new ethic emerged from the new perspective. It was an ethic that recognized that the Earth was not large enough nor the resources plentiful enough to tolerate, for any long-term future, the escalation of the anthropocentric and aggressive technical behavior of humans. The new awareness placed into context the question of education for the citizens of the world. The focus became one of knowledge and understanding of the

relation of technical means to biological and social systems and the behavior of the Earth as a total living system.

Two directions began to emerge, one social and one biological. The social direction focused on the organization of society and the creation of technical systems that contributed toward agreed-upon social purposes such as full employment, an enhanced quality of life for all people of all ages and long-term sustainability of communities. The second, biological, focused on the creation of technical systems based on biological design and operating principles that contributed to the well being of all people and the sustainability of the social order and the living Earth. These were the new, yet old, biotechnologies. Each of these foci altered the rationale for, and the content and structure of, technology education. The mission became one of considerable importance, given the nature of the responsibility of citizens to redesign their technical systems within the tenets of the new paradigm.

Ethics and Responsibility

The more the investigations and research continued, the more it became evident that the major problems humans were facing with their technical means were ethical in nature. And as Hans Jonas concluded in his analysis of the dilemma, this was logical. As the nature of human actions changed there was a call for ethics to change as well (Jonas, 1984). The massive changes in technical means, with the accompanying potential for creation and destruction, brought forth problems previous ages never imagined. Jonas pointed out that a significant difference developed as technical means gained in complexity and magnitude. Whereas earlier technical means were practiced in the "proximate sphere," the new technical means overshadowed the neighbor ethics of justice, charity and honesty. The new sphere was one collective action where the doer, deed and effect were changed drastically. The doer was no longer someone known personally. The deed was often outside the community and the effects could be worldwide. The enormity of the power of the technical means thus forced upon ethics a new dimension of responsibility never before contemplated (Jonas, p. 6).

The implications for formal education and specifically technology education became very clear. When the magnitude and impact of collective and aggregate actions using the powerful and complex technical means of the 21st Century became clear it also became clear that significant changes were necessary in education and public policy world-

wide. Jonas reminded the leaders that this required an imperative of a new sort. He stated:

"If the realm of making has invaded the space of essential action, then morality must invade the realm of making, from which it has formally stayed aloof, and must do so in the form of public policy..., the changed nature of human action changes the very nature of politics" (Jonas, 1984).

The ethics of the new paradigm placed new levels of responsibility on each individual as well as on society in general. Concern for the future and what Pirre Crosson called intergenerational equity permeated the thinking. The new ethic charged "each generation with managing the environment so as to pass an unimpaired capacity for existence to the next generation" (Crosson, 1986). The appropriateness of human actions was judged on whether the effects of a given action were "compatible with the permanence of genuine human life" (Jonas, 1984). Technology education programs grounded in this ethic focused on a commitment to preparing citizens with knowledge and competencies in the technologies that would enable each citizen to become a good steward of the Earth. The new programs of technology education were committed to education that provided the knowledge and skills required to design and use technical means that were compatible with human and social needs and the living Earth. This was in a context that recognized that technical means are means only and must be subservient to human and social needs and the life-giving and life-sustaining Earth.

The role of technological knowledge and understanding continued to be critical with respect to meeting basic human needs. However, as the new paradigm evolved, the importance of knowledge and understanding of the creation and utilization of the adaptive systems—tools, machines, materials, techniques and technical means—and the relation of the behavior of these elements and systems to humans, society and the environment became a prime focus of formal education. It was not possible to have intelligent and responsible human action in the creation and use of technical means without a thorough grounding in the behavior of technical means in relation to the biosphere. Technological knowledge had a new context and a new role. The new context placed the creation and use of technological knowledge in a moral realm. It was an entirely new imperative that Hans Jonas articulated so well.

The biosphere as a whole and in its parts, now subject to our power, has become a human trust and has something of a moral claim on us not only for our ulterior sake but for its own and in its own right (Jonas, 1984).

REDIRECTING TECHNICAL MEANS

The redirection of technical means for human and ecological purposes required a holistic focus. This holistic focus required the redirection of the purpose, content, structure, and processes of education. The new context directed an ecocentric focus to human and social purpose and the design and development of appropriate technical and social means to attain collectively agreed-upon goals.

An Evolving World View

The holistic focus derived its characteristics from the evolving world view. The evolving world view was characterized by nine key elements, each of which became part of the program for developing new programs in technology education, as did the new ethic.

- a focus on an ecologically feasible and sustainable society
- the maximization of the possibilities for the development of the person
- a stable ecosystem
- the use of alternative, appropriate and environmentally sympathetic technical means
- personal and community development in addition to economic development
- an intrinsic rather than an anthropocentric relational perspective
- the design of appropriate, nonviolent, technical means compatible with humans and their needs and the living Earth
- the goals of decentralization, regionalism, and small-scale, ecologically sound communities based on the conservation ethos, long-term perspectives, a regenerative biotechnology base, cooperativeness, diversity of life styles and technical means, and work as purposive and self-fulfilling
- human perfection and development (Drengson, 1983; Maroyama, n.d.; Pepper, 1984; and Sale, 1985)

A New Ethic

The redirection was guided by a new ethic, an ethic that transcended the uncontrolled, ad hoc, undisciplined approaches to the introduction and utilization of technical means. The new ethic consisted of five sub-ethics. They were:

- The **humanistic ethic** that directed individual and collective human action toward the enhancement of human development and personal growth, not the technical enterprise.
- The **ecological ethic** that recognized the critical relation between the quality of human life and the living Earth.
- The **global ethic** that directed attention to the understanding of humans, social systems, technical systems, and the living Earth as one whole system.
- The **future ethic** that recognized the critical nature of human choices and their long-term impact on humans, society and the life-giving and life-sustaining environment.
- The **enabling ethic** grounded in the understanding that technological systems can be designed to be compatible with the living Earth and that the design and development of appropriate technical means will enable human beings to create sustainable quality futures.

A New Grounding for Technology Education

The last ethic, in relation to the other four, directed attention to the fact that the evolving paradigm required a **type**, **level** and **quality** of technological literacy of every citizen that was totally different from the literacy required of citizens in the era of the industrial-scientific paradigm. The type and level of technological literacy required by the industrial-scientific world view was a limited and restricted form of literacy when compared to the new world view. This was primarily because of the authoritarian, hierarchical, compartmentalized and specialized structure of the technical enterprise of the industrial-scientific era. The underlying principles of the new paradigm required not only a new higher level of understanding of the behavior of technological systems, but also a more comprehensive understanding of the total ecotechnical system.

The reason for the increased level of technological literacy required of citizens in the new era was the participatory nature implied in the evolving paradigm. As the regions of the world moved toward the enhancement of individual freedom and responsibility, it became

apparent that technologically illiterate citizens would promote, by default, the demise of democracy and the destruction of the natural environment and place in control an elite group of people who would control the processes of public and private life. It was also apparent that the new levels of responsibility required of each citizen as a creator or user of technical means new levels of ecotechnical knowledge and understanding.

The purpose, goals, content, structure and processes of technology education became grounded in the tenets of the new paradigm.

ADDRESSING THE CHALLENGE

The relation between humans, their technical means and the environment were totally different in the new era than in the time of Aristotle, the Middle Ages, or of the Industrial Revolution. The continued creation and use of technical means had altered human potential. These creations also ended the age of innocence. There came about a stark realization that the powerful and disruptive technical means that had been created by some humans could, in the control of the ignorant and socially insensitive, bring about untenable futures for humankind and possibly even destroy civilization as known and life on Earth.

It became clear that earlier perceptions of progress were flawed; and that the goals of material possessions, profit, continued growth and security through increasing armaments would not lead to a better world or a sustainable society. A new form of survival knowledge was required. There was a need to manage the human order so as to assure the continuation of life. The latter would require a self-conscious, intelligent management of the Earth and the biosphere. This became one of the great challenges facing humanity in the 21st Century.

TECHNOLOGY EDUCATION IN THE 21ST CENTURY

The technological literacy that evolved during the latter part of the 20th and early part of the 21st Century focused on three primary areas. They were: (1) technology and progress; (2) technology and the environment; and (3) technology and ethics. There were several central themes that permeated the literacy thrust. These evolved from the values and beliefs of the new paradigm. Included was a **design focus** that had as primary tenets: stewardship and biosystem compatibility,

human scale, balance, harmony, sustainability and biological and technological diversity.

The new technological literacy also incorporated knowledge of the physiotchnologies and the biotechnologies. Successful design required a knowledge and understanding of the structure and behavior of the physio and biotechnologies and the relation of these technologies to human society and the natural environment. The new technological literacy became a part of the common learnings of citizens. Knowledge of and competency in the technologies became part of a consensus of what it meant to be culturally and liberally educated; what it meant to be prepared to be a responsible citizen. Knowledge of the behavior of technological systems came to be recognized as a fundamental component of the common learnings of basic education for **all** citizens and not members of special groups.

THE TRANSITION

There was concern during the period of transition to the new curriculum in technology education that traditional educators would misinterpret or confuse the nature of the change required as had been the case so often in the past. The concern was that programs would be established that would offer courses **about** technology rather than courses **in** technology. Courses and programs **in** technology are those where the technical systems are taught and mastered. Courses **about** technology provide information about technical systems, but students seldom gain the knowledge and understanding necessary for comprehending the behavior of the systems so they can apply the knowledge effectively. Courses **in** technology develop the ability to use the intellectual processes of the technologist by having direct experiences in the technologies (Slaght, 1987). It was determined that true literacy would require a sustained effort over many years of formal education if knowledge and understanding of the abstract concepts and ethics upon which the technical world was created and functioned was to be comprehended to the level required for citizens to function effectively and responsibly. This level of understanding was not reached by hearing or reading about inventions and technical systems. What was required was direct and sustained involvement in the processes of the technologist. The mind must be prepared to be capable of observing and establishing differences, similarities and relationships. Some were

concerned about this requirement for the new basic: technological literacy. However, it was found that human beings were not only perceptual beings, they were also conceptual. They were capable of learning and using technological modes of thought—the intellectual processes and modes of inquiry of the new science of technology.

Those involved in the new sciences of physiotechnology and biotechnology were concerned with investigating and determining the behavior of the elements and components of the systems and with the design of systems that enhance life on Earth. The goals of these sciences were predictability, replication, reliability, optimization, and compatibility of their designs with living systems. They were involved intellectually in problem identification, analysis of data, visualization, computing, measuring, designing, creating, experimenting, testing, and simulating new or alternative technical means. They pursued the creation of the new knowledge systematically.

THE NEW MISSION

The new literacy did not depend on geometric curriculum models of great complexity. The mission was quite clear. Create and implement a system of basic education for all that prepared citizens to contribute responsibly and effectively in creating and operating a technological base for their societies that was symbiotic, regenerative, and low in entropy.

Progress in the past had been through creative endeavors in the physiotechnologies and the technical systems of communication, production, and transportation. These systems were still the primary technological systems of any successful society. These systems were created to utilize the inputs of the inanimate resources of the Earth and to transform these resources physically to create the necessary components of the adaptive systems of society. The processes of the physical technologies were essentially nonrenewable and continually depleted the resources of the Earth or transformed them into unusable or toxic form. These systems, as originally designed, were high in entropy. The focus of the new literacy was on the redesign of these systems; to reduce their entropy and enhance their compatibility with the natural environment.

The new literacy incorporated the study of a new form of technical means, the biotechnologies. The biotechnologies were those means identified or created by humans that utilized knowledge of the natural

and human systems in the design of adaptive systems. The focus of the biotechnologies was on the natural order; the design of technical systems utilizing knowledge of the natural order and living organisms or their components in the creation, processing, or recycling of resources for the several adaptive systems.

The processes of the biotechnologies were renewable and held the promise of being compatible with the natural systems and not depleting the resources of the Earth or transforming them into non-renewable forms. The processes of the biotechnologies are low in entropy, symbiotic, and renewable. Examples include: housing design compatible with the local resources and the natural environment; use of biomass for methane generation; waste disposal utilizing bacteria and water hyacinths; food processing, as yogurt, cheese, beer and wine; the use of micro-organisms to produce pharmaceuticals and biodegradable designer materials in the form of new plastics; and enhanced recovery of minerals and oil to aid in pollution control. The design-with-nature focus of the biotechnologies included new approaches to the energy problems of society. The development of the hydrogen economy, utilizing the sun as the primary energy source for converting water to hydrogen and oxygen, eliminated the many problems associated with other forms of energy and assured a renewable source of nonpolluting energy.

Technological literacy was thus focused on a new vision of the nature and characteristics of technical means in the social order. It became possible to entertain the creation of technical systems uniquely designed to be compatible with each bioregion of the Earth. The new paradigm brought forth the possibility of diverse, decentralized, heterogeneous, sustainable societies throughout the Earth. The field of technology education thus faced the difficult task of addressing this challenge. The criteria for the identification of the structure and content of technology education was imbedded in the tenets of the new paradigm. And although the curricula for each bioregion would be different, there were constants.

The constants were derived from the understanding that the new literacy involved the systematic study of the creation, utilization, and behavior of adaptive systems (tools, machines, materials, techniques, and technical means—physio or bio) and the behavior of these elements and systems in relation to humans, their societies, and the living Earth.

The process of the new literacy was design. Design was an element of the field of technology education that was often overlooked in the 20th Century when the focus was often limited to geometric models of the curriculum structure. With the evolution of the new cultural paradigm, design became quite central to the field. Closely related to design, creativity, invention, and innovation were the elements of valuing and assessing. These elements were central to guiding the continual corrections and adjustments required to attain the desired long-term goals of the new paradigm, whether they related to shelter, energy, food, and clothing or to the large scale infrastructures and systems associated with communicating, resource transformation, or transporting.

The focus of new literacy on the theme of "design with nature" and the GAIA Hypothesis directed the program of work of technology education in the 21st Century toward the evolving sub-discipline of biotechnology which held the promise of enabling the creation of technical means that contributed to the creation of a long-term sustainable and preferable human future for all throughout the living Earth.

The challenge was straightforward: design adaptive systems that are compatible with the natural systems of the living Earth and that will enable humans to attain all they are capable of being. This became the vision. The rest was commentary.

COMPILED REFERENCE¹

- (1981). *Occupational and Practical Arts Futuring Project*. Albany, NY: New York State Education Department. [Chapter 2]
- (1984). *The Illinois Plan for Industrial Education*. Springfield, IL: Department of Adult, Vocational and Technical Education. [Chapter 2, 7]
- (1985, June). *Science & technology for tomorrow's world*. Report of Exeter II conference on secondary school science education, Exeter, New Hampshire. ERIC ED 276 575 [Chapter 7]
- (1986, March). Composite materials. *The Technology Teacher*, 43(6), 15-21. [Chapter 2]
- (1987). *Design and Technology Education*. Brochure. Tenth International Design and Technology Education Exhibition, Birmingham, UK. [Chapter 6]
- (1988). *Omnibus Trade and Competitiveness Act*. Washington, DC: U. S. Congress. [Chapter 5]
- (1988, March 6). U. S. students lag in science learning. *Columbia Daily Tribune*, Columbia, MO, p. 26. [Prologue]
- (1988, September 11). Workers reaping rewards of industrial revolution. *Sunday World-Herald*, Omaha, NB. Section G, p. 1. [Chapter 7]
- (n.d.). *City Works*. Minneapolis, MN: City Works Project. [Chapter 6]
- (1985). The S-STS Program. *NLA News*, 11(2), 1. [Chapter 8]
- (1986). *Science, Technology and Society*. Conference announcement brochure. University Park, PA: The Pennsylvania State University. [Chapter 6]
- (1987). *Interface '87*. Eleventh Annual Humanities and Technology Conference, Southern College of Technology, The Humanities and Technology Association. [Chapter 6]
- (1988, July 3). The new high-tech battleground. *New York Times*, Section 3, 1, 8. [Chapter 4]
- Adler, M. (1982). *Paidea proposal: An educational manifesto*. New York: Macmillan. [Chapter 7]
- Adler, P. S. (1987). Automation & skill; New directions. *International Journal of Technology Management*, 2(5-6), 761-772. [Chapter 5]
- Advanced Center for Technology Training. (1987). Brochure. Farmington Hills, MI: ACTT. [Chapter 6, 7]
- AFL-CIO Committee on the Evolution of Work. (1983). *The future of work*. Washington, DC: AFL-CIO. [Chapter 5]
- AFL-CIO. (1988). *Here comes tomorrow: Technological change and its effects on professional, technical and office employment*. Washington, DC: Department for Professional Employees. [Chapter 5]
- American Association for the Advancement of Science. (1989). *The nature of technology*. Washington, DC: AAAS. [Chapter 9]
- American Association for the Advancement of Science. (1985). *Project 2061: Education for a changing future*. Washington, DC: AAAS. [Prologue, Chapter 7]

¹This list is compiled across all chapters to conserve space and insure consistency of citation. Authors citing each source are indicated by chapters in [] at citation end.

- American Association for the Advancement of Science. (1989). *Science for all Americans*. Summary report of Project 2061. Washington, DC: AAAS. [Chapter 6, 7]
- American Association for the Advancement of Science. (1989). *The designed world*. Washington, DC: AAAS. [Chapter 9]
- American Vocational Association. (1988, September 16). National Academy urges vo-ag reform, agricultural literacy. *Legislative Brief*, 1(18). [Chapter 7]
- Amin, A., & Goddard, J. (1986). *Technological change, industrial restructuring and regional development*. London, UK: Allen & Unwin. [Chapter 4]
- Anderson, R. E., & Parnell, J. O. (1988). Well-planned study abroad offers invaluable experience. *School Shop*, 47(9), 26-27. [Chapter 3]
- Arp, H. (1989). Some applications of the concept of general technology. In F. de Klerk Wolters, I. Mottier, J. Raat, & M. de Vries (Eds.), *Teacher Education For School Technology*, proceedings of the Pupils Attitude Toward Technology (PATT). Conference IV, (pp. 45-56), Eindhoven, The Netherlands, April 13-18, 1989. Eindhoven, The Netherlands: Pedagogical Technological College. [Chapter 7]
- Atkinson, R. C. (1984, March 30). Education for an age of sciences. *Science*, 223(4643), 335. [Chapter 7]
- Ayers, R. U. (1988). Technology: The wealth of nations. *Technological Forecasting and Social Change*, 33, 189-201. [Chapter 11]
- Bailey, H. S. (1957, May). How to be literate in a scientific age. *Saturday Review*, 13-15. [Chapter 1]
- Bame, E. A. (1986). Middle/junior high technology education. In R. E. Jones & J. R. Wright (Eds.), *Implementing Technology Education*, 35th yearbook of the American Council on Industrial Arts Teacher Education, (pp. 70-94). Bloomington, IL: McKnight. [Chapter 2]
- Barnes, J. L. (1986). *Curriculum organizers for technology*. Paper presented at the American Vocational Association conference, December 8, 1986. Ypsilanti, MI: Author, Eastern Michigan University. [Chapter 7]
- Barnes, J. L. (1987). *An international study of curricular organizers for the study of technology*. Unpublished doctoral dissertation. Blacksburg, VA: Virginia Polytechnic Institute and State University. [Chapter 7]
- Barnes, J. L. (1988). Examining technology curricula in countries around the world. *School Shop*, 47(9), 50-52. [Chapter 3]
- Barnes, J. L. (1988). Learning to solve tomorrow's problems. *The Technology Teacher*, 48(6), 25-29. [Chapter 5]
- Barnes, J. L. (1988). Personal communication. Ypsilanti, MI: Author, Eastern Michigan University. [Chapter 7]
- Beckmann, J. (1806). *Entwurf der allgemeinen technologie*. Göttingen, FRG: Joh. Friedr. Röver. [Chapter 7]
- Behnke, J. (1960, April). Scientific literacy. *AIBS Newsletter*, 21-22. [Chapter 1]
- Bell, D. (1973). *The coming of post-industrial society*. New York: Basic Books. [Chapter 7]
- Bell, L., Korb, G., & Simpson, M. (1982, Fall). *The 4C's of technological literacy*. Unpublished class project pursuant to a grant from the Stout University Foundation. Menomonie, WI: University of Wisconsin-Stout. [Chapter 7]

- Belous, R. S. (1989). *The contingent economy: The growth of the temporary, part-time and subcontracted workforce*. Washington, DC: National Planning Association. [Chapter 4]
- Benderson, A. (1983, November). Computer literacy. *Focus* (Educational Testing Service), 19, 1-32. [Chapter 7]
- Bensen, M. J. (1988). Challenges and prospects at the international level. *School Shop*, 47(9), 46-49. [Chapter 3]
- Billington, D. P. (1985, December). Technology and the teaching of values. *AAHE Bulletin*, 8-10. [Chapter 7]
- Bishop, J. (1989, September). Incentives for learning: Why American high school students compare so poorly to their counterparts overseas. In Commission on Workforce Quality & Labor Market Efficiency, *Investing In People: A Strategy to Address America's Workforce Crisis*, Background Papers Volume I, (pp. 1-84). Washington, DC: U. S. Department of Labor. [Chapter 4]
- Bjorkquist, D. C., & Swanson, R. A. (1981, May). Technology education: A good beat, but hard to dance to. In L. Smalley (Ed.), *Technology Education Symposium II—Technological Literacy*, proceedings, (pp. 14-17). Menomonie, WI: University of Wisconsin-Stout. ERIC ED 206 915 [Chapter 1]
- Blakemore, A. E. (1987). The new economics of personnel. *Journal of Labor Economics*, 5(4), Part 2. [Chapter 4]
- Booth, R. J. (1989, July). A curricular framework for technology teacher training and education. In F. de Klerk Wolters, I. Mottier, J. Raat, & M. de Vries (Eds.), *Teacher Education For School Technology*, proceedings of the Pupils Attitude Toward Technology (PATT) Conference IV, (pp. 107-120), Eindhoven, The Netherlands, April 13-18, 1989. Eindhoven, The Netherlands: Pedagogical Technological College. [Chapter 7]
- Bowden, G. (1982, Fall). Becoming a scientific literate nation. *Educational Record*, 63(4), 5-8. [Prologue, Chapter 7]
- Boyer, E. L. (1983). *High school: A report on secondary education in America*. The Carnegie Foundation for the Advancement of Teaching. New York: Harper & Row. [Chapter 7]
- Boyer, E. L. (1985). A perspective on education. In *Technology Education: A Perspective on Implementation*. Reston, VA: International Technology Education Association. [Chapter 9]
- Braden, P. V. (1987). The impact of technology on the workforce. *Community, Technical, and Junior College Journal*, 58(3), 24-29. [Chapter 4]
- Brewer, R. L. (1988). Bringing Japan's approach to a vocational school in the heart of the USA. *School Shop*, 47(9), 43-45. [Chapter 3]
- Brockway, J. P. (1987). Technology & the liberal arts: Are we producing technopeasants? In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, (pp. 39-45) May 13-15. Columbus, OH: The Ohio State University. [Chapter 2]
- Burke, J. (1978). *Connections*. Ten program television series. London, UK: British Broadcasting Corporation. Boston, MA: Little Brown. [Chapter 10]

- Campanella, A. (1987, May 14). Technology. Keynote address to the Technology Education Conference - 1987 held at the New Jersey Bell Corporate Training Center, South Plainfield, New Jersey. [Prologue]
- Campbell, M. B. (1988). Comparing IA/TE programs in western European nations. *School Shop*, 47(9), 20-22. [Chapter 3]
- Carlton, R. (Ed.). (1963, April). On scientific literacy. *NEA Journal*, 52(4), 33-35. [Chapter 1]
- Cetron, M., Rocha, W., & Luckins, R. (1988). Into the 21st century: Long-term trends affecting the United States. *The Futurist*, 22(4), 29-40. [Chapter 5]
- Chall, J. S. (1983). *Stages of reading development*. New York: McGraw-Hill. [Chapter 7]
- Chamot, D. (1988, April). The industrial revolution and the information revolution: Is social upheaval inevitable? *Toqueville Research Parallels*, No. 6, Toqueville Asset Management Corporation, New York. Reprinted in entirety in *Manufacturing Competitiveness Frontiers*, 12(7), 1-9, Manufacturing Productivity Center, Illinois Institute of Technology, Chicago, Illinois, July 1988. [Chapter 5]
- Chamot, D., & Baggett, J. N. (Eds.). (1979). *Silicon, satellites and robots: The impacts of technological change on the workplace*. Washington, DC: Department for Professional Employees, AFL-CIO. [Chapter 5]
- Clark, J. P., & Flemings, M. C. (1986). Advanced materials and the economy. *Scientific American*, 255(4), 50-57. [Chapter 4]
- Clem, O. M. (1950). Are you educated in science? *School Science and Mathematics*, 50, 681-686. [Chapter 1]
- Cochran, L. (1970). *Innovative programs in industrial education*. Bloomington, IL: McKnight. [Chapter 1]
- Commission on Technology Education. (1987). *Technology education: Learning how to learn in a technological world*. Report of the Commission on Technology Education for the State of New Jersey. Upper Montclair, NJ: Department of Industrial Studies, Montclair State College. ERIC ED 288 743 [Chapter 7]
- Commission on Workforce Quality & Labor Market Efficiency. (1989, September). *Investing in people: A strategy to address America's workforce crisis*. Washington, DC: U. S. Department of Labor. [Chapter 4, 7]
- Council for the Understanding of Technology in Human Affairs. (1986, Spring). *The Weaver*, CUTHA, Brown University. [Chapter 6]
- Council for Understanding of Technology in Human Affairs. (1986). Brochure. Bethlehem, PA: Lehigh University. [Chapter 6]
- Council of Supervisors, International Technology Education Association. (1989). Preparing facilities to deliver technology literacy. Unpublished document. Reston, VA: CS-ITEA. [Chapter 9]
- Creticos, P. A., & Sheets, R. G. (1988). *State-financed, workplace-based retraining programs: Policy issues*. Oak Park, IL: Creticos and Associates, Inc. [Chapter 4]
- Cross, A., & McCormick, B. (Eds.). (1986). *Technology in schools*. Milton Keynes, UK: Open University Press. [Chapter 7]

- Crosson, P. (1986, May). Sustainable food production: Interaction among natural resources, technology and institutions. *Food Policy*, II(2), 143-156. [Chapter 11]
- Culberson, G., & Carter, L. (1988). Craft, design, and technology in the United Kingdom. *School Shop*, 47(9), 28-29. [Chapter 3]
- Cutcliffe, S. H. (1981, May). Technological literacy for the nontechnologist. In L. Smalley (Ed.), *Technology Education Symposium II—Technological Literacy*, proceedings. Menomonie, WI: University of Wisconsin-Stout. ERIC ED 206 915 [Chapter 7]
- Cyert, R. M., & Mowery, D. C. (Eds.). (1987). *Technology and employment: Innovation and growth in the U. S. economy*. Washington, DC: National Academy Press. [Chapter 4]
- Daiber, R. A., & Wright, J. (1981, March). *A technological literacy scale: A visual primer for technology education*. Paper presented at the American Industrial Arts Association conference, Pittsburgh, PA, March 23-27. St. Jacob, IL: Author. [Chapter 7]
- Daiber, R., & LaClair, T. (1986). High school technology education. In R. E. Jones & J. R. Wright (Eds.), *Implementing Technology Education*, (pp. 95-137), 35th yearbook of the American Council on Industrial Arts Teacher Education. Bloomington, IL: McKnight. [Chapter 8]
- Davis, G. B. (1980). CAM: A key to improving productivity. *Modern Machine Shop*, 53(4). [Chapter 2]
- de Vries, M. (1987). The school subject 'Technology': A subject without tradition. In R. C. van den Bergh (Ed.), *Report: PATT-Conference, Volume 2, Contributions*, proceedings, (pp. 26-32), Eindhoven, The Netherlands, April 9-14. Eindhoven, The Netherlands: Eindhoven Technological University. [Chapter 3]
- Deforge, Y. (1981). *Living tomorrow...An inquiry into the preparation of young people for working life in Europe* (3rd. ed.). Opinion papers series. Strasbourg, France: Council of Europe. ERIC ED 204 491 [Chapter 7]
- Deforge, Y. (1984). La Préparation aux études et formations qui font suite a la scolarite obligatoire. Preparation of students for studies and training beyond compulsory education. *Orientation Scolaire et Professionnelle*, 13(3), 179-189
- Dennis, E. A. (Compiler). (1988). *Industrial Teacher Education Directory* (28th ed.). Jointly sponsored by the National Association of Industrial and Technical Teacher Educators and the Council on Technology Teacher Education. Cedar Falls, IA: University of Northern Iowa. [Chapter 6]
- Department of Education and Science. (1967). *Reports of education #40—Rethinking the curriculum*. London: Her Majesty's Stationery Office. [Chapter 3]
- Department of Education and Science. (1985). *Building bulletin #63—Craft, design and technology: Accommodations in secondary schools*. London: Her Majesty's Stationery Office. [Chapter 3]
- Department of Education and Science. (1989, June). *Design and technology for ages 5 to 16*. London: Her Majesty's Stationery Office. [Chapter 3]
- Deutch, J. M. (1986, Fall). Warp & Woof. *The Weaver*, 5(1), 1. [Prologue]

- DeVore, P. W. (1972, May). *Education in technological society: Access to tools*. Mimeo. Morgantown, WV: West Virginia University. [Chapter 2]
- DeVore, P. W. (1973). *Structure and content foundations for curriculum*. Washington, DC: American Industrial Arts Association. [Chapter 7]
- DeVore, P. W. (1980). *Technology: An introduction*. Worcester, MA: Davis. [Chapter 2, 5, 7]
- DeVore, P. W. (1985). *Differentiating between science and technology*. Paper presented at the Annual Conference of the International Technology Education Association, San Diego, CA. ERIC ED 265 407 [Prologue]
- DeVore, P. W. (1986). Measuring technological literacy: Problems and issues. *Bulletin of Science, Technology and Society*, 6, 202-209. [Chapter 1]
- DeVore, P. W. (1987). 2030 A.D.: Critical paths to 2080 A.D. In M.R. Kozak & J. Robb (Eds.), *Technology Education Symposium IX*, proceedings, (pp. 63-74). Denton, TX: North Texas State University. [Prologue, Chapter 2]
- DeVore, P. W. (1987). Science and technology: An analysis of meaning. *The Journal of Epsilon Pi Tau*, 13(1), 2-9. [Chapter 7]
- DeVore, P. W. (1987, April 20). Personal correspondence to the editor. Morgantown, WV: Author. [Chapter 7]
- DeVore, P. W. (1987, March 26). *Measuring technological literacy*. Paper presented at the International Technology Education Association Conference, Tulsa, Oklahoma, March 23-27, 1987. Morgantown, WV: Author, West Virginia University. [Chapter 7]
- DeVore, P. W. (1987, May). Dichotomies, relationships and the development of technological literacy. In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13-15. Columbus, OH: The Ohio State University. [Chapter 7]
- Dodd, T. (1978). *Design and technology in the school curriculum*. London: Hodder & Stoughton. [Chapter 3]
- Doty, D. B. (1979, September). The significance of skill. *Industrial Arts Division Insider. VocEd*, 54(6), 30a-c. [Chapter 7]
- Drengson, A. R. (1983). *Shifting paradigms: From technocrat to planetary person*. Victoria, B. C., Canada: Lightstar Press. [Chapter 11]
- Dugger, W. E., Jr. (1988). Making progress worldwide towards technology education. *School Shop*, 47(9), 52-53. [Chapter 3]
- Dugger, W. E., Jr., Bame, E. A., & Pinder, C. A. (1985). *Standards for technology education programs*. South Holland, IL: Goodheart-Willcox. [Chapter 9]
- Dyrenfurth, M. J. (1984). *Literacy for a technological world*. Information Series No. 266. Columbus, OH: The National Center for Research in Vocational Education. ERIC ED 241 715 [Chapter 1, 2, 6, 7]
- Dyrenfurth, M. J. (1987). International perspectives on technological literacy. In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13-15, (pp. 19-37). Columbus, OH: The Ohio State University. [Chapter 2, 8]
- Dyrenfurth, M. J. (1987). Technological literacy: A model for society's most urgent imperative. In R. C. van den Bergh (Ed.), *Report: PATT-Conference, Volume 2, Contributions*, proceedings, (pp. 266-285), Eindhoven, The Netherlands, April 9-14. Eindhoven, The Netherlands: Eindhoven University of Technology. [Chapter 3]

- Dyrenfurth, M. J. (1988). International perspectives on technological literacy and the education about technology. In J. Raat, R. C. van den Bergh, F. de Klerk Wolters, & M. de Vries (Eds.), *Basic Principles of School Technology*, Volume 2, PATT III conference proceedings, (pp. 202-208), Eindhoven, The Netherlands. Eindhoven, The Netherlands: Eindhoven University of Technology. [Chapter 3, 7]
- Dyrenfurth, M. J. (1989). *Technological literacy: A necessary condition for manufacturing's future success*. Research Report. Columbia, MO: Applied Expertise Associates. [Prologue]
- Dyrenfurth, M. J., & Lemons, D. (1982, May). Vocational education's role in developing technological literacy. *Canadian Vocational Journal*, 18(1), 32-35. ERIC EJ 262 775 [Chapter 7]
- Educational Policies Commission. (1961). *The central purpose of American education*. Washington, DC: National Educational Association. [Chapter 2]
- Educational Testing Service. (1986). *Annual report: Testing for tomorrow*. Princeton, NJ: Author. [Chapter 7]
- Ehrlich, E. (1989, June 14). Information technology, global linkage, and U. S. competitiveness. *Vital Speeches of the Day*, 755-759. [Chapter 5]
- Engineering Concepts Curriculum Project. (1971). *Man made world*. New York: Polytechnic Institute of Brooklyn. [Chapter 7]
- Erekson, T. L. (1986, October). Illinois Center for Technological Literacy: A response by the University of Illinois. In M. Sanders (Ed.), *Technological Literacy: An Educational Mandate*, proceedings of the Technology Education Symposium VIII, (pp. 12-15), October 17-18. Blacksburg, VA: Virginia Polytechnic Institute and State University. [Chapter 6]
- Erekson, T. L. (1987). 2030 A.D.: The role of the technology teacher educator. In M.R. Kozak & J. Robb (Eds.), *Technology Education Symposium IX*, proceedings, (pp. 37-39). Denton, TX: North Texas State University. [Chapter 2]
- Erekson, T. L. (1989, July 26). *Integrating technology into the curriculum*. Paper presented at the Missouri Industrial Technology Education Association summer conference. Springfield, MO: Author. [Chapter 7]
- Evans, H. (1962, October). Toward scientific literacy. *Teachers College Record*, 64(1), 74-79. [Chapter 1]
- Feinberg, W., & Rosemont, H., Jr. (Eds.). (1976). *Work, technology, and education: Dissenting essays in the intellectual foundations of American Education*. Urbana, IL: University of Illinois Press. [Prologue]
- Fleming, R. (1987). *Technological literacy: A common essential learning for Saskatchewan students*. Regina, Saskatchewan, Canada: Saskatchewan Department of Education. ERIC ED 286 737 [Chapter 3, 7]
- Flynn, P. M. (1988). *Facilitating technological change: The human resource challenge*. Cambridge, MA: Ballinger. [Chapter 4, 5]
- Foster, P., & Perreault, R. (1986, Summer/Fall). Characteristics of technological literacy: Perspectives from the industrial and educational sectors. *The Journal of Epsilon Pi Tau*, 12(1), 53-58. ERIC EJ 337 076 [Chapter 1, 7]
- Frey, R. E. (1987, November 11). *Is there a philosophy of technology?* Unpublished paper presented at the 74th Mississippi Valley Industrial Teacher Education Conference, November 11-13, 1987, Chicago. North Newton, KS: Bethel College. [Chapter 7]

- Friedman, E. A. (1980, December). Dimensions of technological literacy in liberal education. *Forum*, 3(3). [Chapter 2]
- Frymier, J., et al. (1986). *Phi Delta Kappa: 2000 and beyond*. The Futures Committee report to the board of directors. Bloomington, IN: Phi Delta Kappa International. [Chapter 6]
- Gasset, J. Ortega y. (1961). *History as a system*. New York: W. W. Norton. [Chapter 11]
- Gendron, B. (1977). *Technology and the human condition*. New York: St. Martin's Press. [Chapter 7]
- Goldman, S. L. (1984). The techne of philosophy and the philosophy of technology. *Research in Philosophy & Technology*, 7, 115-144. [Chapter 7]
- Goldman, S. L., & Cutcliffe, S. H. (1982). STS, technology literacy, and the arts curriculum. *Bulletin of Science, Technology, Society*, 2, 291-307. [Chapter 6]
- Goor, I. (1988, October 19). A formula for the future creating value in industry. *Vital Speeches of the Day*, 190-192. [Chapter 5]
- Gradwell, J. B. (1988, February). Twenty years of technology education. *The Technology Teacher*, 47(5), 30-33. [Chapter 7]
- Graham, M. B. W., & Rosenthal, S. R. (1985). *Flexible manufacturing requires flexible people*. Boston, MA: Boston University, Manufacturing Roundtable Research Report. [Chapter 5]
- Graubard, S. R. (Ed.). (1983). Scientific literacy. *Daedalus*, 112(2). [Chapter 7]
- Grodzka-Borowska, A., & Szydłowski, H. (1989). Technological literacy in the curriculum of Polish elementary school and technology teacher training. In F. de Klerk Wolters, I. Mottier, J. Raat, & M. de Vries (Eds.), *Teacher Education For School Technology*, proceedings of the Pupils Attitude Toward Technology (PATT) Conference IV, (pp. 416-432), Eindhoven, The Netherlands, April 13-18, 1989. Eindhoven, The Netherlands: Pedagogical Technological College. [Chapter 7]
- Haberer, J. (1986). Technological literacy and the university: Concepts, priorities and political realities. *Bulletin of Science, Technology and Society*, 6(2 & 3), 222-228. [Chapter 1]
- Halfin, H. H. (1973). *Technology—A process approach*. Doctoral dissertation. Morgantown, WV: West Virginia University. *Dissertation Abstracts International*, 34, 1586-A. [Chapter 7]
- Hallett, J. (1987). *Worklife visions*. Alexandria, VA: American Society for Personnel Administration. [Chapter 5]
- Hannay, N. B., & McGinn, R. E. (1980, Winter). The anatomy of modern technology: Prolegomenon to an improved public policy for the social management of technology. *Daedalus*, 109(1), 25-53. [Chapter 7]
- Harris, L., et al. (1970). *Survival literacy study*. New York: Louis Harris and Associates. [Chapter 2]
- Harrison, G. B., & Dutton, P. E. (1988, March). Frameworks and communication for technology education. Draft interim report of conference at Rugby. Nottingham, UK: Trent Polytechnic. [Chapter 7]
- Hatch, L. O. (1985). *Technological literacy: A secondary analysis of the National Assessment of Educational Progress science data*. Unpublished doctoral dissertation. College Park, MD: University of Maryland. [Chapter 7]

- Hawkins, L., & Harder, J. (1988). *Goals and objectives for technology education at Mayfield Junior High*. Oklahoma City, OK: Putnam City Public Schools. [Chapter 9]
- Heller, M. (1982, May). Computer literacy: Speaking for the illiterates. *Technological Horizons in Education*, 9(4), 89. [Chapter 7]
- Helsel, L. D., & Jones, R. E. (1986). Undergraduate technology education: The technical sequence. In R. E. Jones & J. R. Wright (Eds.), *Implementing Technology Education*, 35th yearbook of the American Council on Industrial Arts Teacher Education, (pp. 171-200). Bloomington, IL: McKnight. [Chapter 2]
- Henak, R. M., & Barella, R. (1986). Undergraduate technology education: The professional sequence. In R. E. Jones & J. R. Wright (Eds.), *Implementing Technology Education*, 35th yearbook of the American Council on Industrial Arts Teacher Education, (pp. 138-170). Bloomington, IL: McKnight. [Chapter 2]
- Hirsch, E. D. (1987). *Cultural literacy: What every American needs to know*. Boston, MA: Houghton Mifflin. [Chapter 7]
- Hodges, M. P., & Lichter, B. D. (1980, May). The union of theory and practice. *Engineering Education*, 70(8), 816-821. [Chapter 7]
- Hood, W. F. A. (1968). *Heideggerian approach to the problem of technology*. Unpublished doctoral dissertation. University Park: The Pennsylvania State University. [Chapter 11]
- Hoyt, K. B. (1988). *The changing face of the workforce: A review of projections covering the period from 1986 to the year 2000*. Paper presented to the national Career Development Association conference, Orlando, Florida, January 13, 1988. Lawrence, KS: Author, Kansas State University. [Prologue]
- Hughes, T. (1989). Letter of response to a survey of state supervisors, unpublished document. [Chapter 9]
- Hurd, P. D. (1958, October). Science literacy: Its meaning for American schools. *Educational Leadership*, 13-16. [Chapter 1]
- Industrial Arts Division. (1953). *A guide to improving instruction in industrial arts*. Washington, DC: American Vocational Association. [Chapter 6]
- International Association of Machinists. (n.d.). *Workers' technology bill of rights*. Washington, DC: IAM. [Chapter 5]
- International Technology Education Association. (1985). *Technology education: A perspective on implementation*. Reston, VA: ITEA. [Chapter 2, 6]
- International Technology Education Association. (1989). *ITEA 1990-95 Professional improvement plan*. Reston, VA: ITEA. [Chapter 6]
- International Technology Education Association. (n.d.). *Technology education: The new basic*. Reston, VA: ITEA. [Chapter 6]
- International Technology Education Association. (n.d.). *This we believe: Technology education*. Reston, VA: ITEA. [Chapter 6]
- Jennings, J. (1987, October). The Sputnik of the eighties. *Phi Delta Kappan*, 69(2), 104-109. [Chapter 6]
- Johnson, J. R. (1989). *Technology: A project 2061 panel report*. Washington, DC: AAAS. [Chapter 6, 7]

- Johnson, P. G. (1962, December). The goals of science education. *Theory into Practice*, 1(5), 239-244. [Chapter 1]
- Johnson, S. D. (1988, Spring). A philosophical base for developing technology education programs. *Illinois Industrial Educator*, 7(3), 2-5. [Chapter 7]
- Johnston, W. B., & Packer, A. H. (1987). *Workforce 2000: Work and workers for the 21st century*. Indianapolis, IN: Hudson Institute. [Chapter 4, 5]
- Jonas, H. (1984). *The imperative of responsibility*. Chicago, IL: University of Chicago Press. [Chapter 11]
- Jones, A. H. (1988). Our field in other nations. *School Shop*, 47(9), 19. [Chapter 3]
- Jones, R. E. (1983, Winter). Implementing a state plan for industrial education curriculum model. *Illinois Industrial Educator*, 2(4), 8-10. [Chapter 2]
- Jones, R. E. (1984, March 28). *A primer for technology education*. Paper presented at the American Industrial Arts Association conference, Columbus, Ohio. Charleston, IL: Author, Eastern Illinois University. [Chapter 7]
- Jones, R. E. (1988). Integrating the systems of technology approach. In W. H. Kemp & A. E. Schwaller (Eds.), *Instructional Strategies For Technology Education*, 37th yearbook of the Council on Technology Education, (pp. 99-109). Mission Hills, CA: Glencoe. [Chapter 2]
- Jones, R. E., & Wright, J. R. (1987). The symposium: Historical perspective and expectations. In M.R. Kozak & J. Robb (Eds.), *Technology Education Symposium IX*, proceedings, (pp. 3-7). Denton, TX: North Texas State University. [Chapter 2]
- Jones, R. E., & Wright, J. R. (Eds.). (1986). *Implementing technology education*. 35th yearbook of the American Council on Industrial Arts Teacher Education. Bloomington, IL: McKnight. [Chapter 2]
- Kasprzyk, S. (1980). The background of a technological society. In H. A. Anderson & M. J. Bensen (Eds.), *Technology and Society: Interfaces with Industrial Arts*, American Council on Industrial Arts Teacher Education's 29th Yearbook. Bloomington, IL: McKnight. [Chapter 7]
- Khaleel, I. A. (1988). Nigerian vo-tech education contributes to society's goals. *School Shop*, 47(9), 36-38. [Chapter 3]
- Kidder, R. M. (1987). Severeid on U. S. Future. *Christian Science Monitor*, 79, 1-6. [Chapter 11]
- Kozak, M. R. (1982, Spring). The evolving profession. *The Journal of Epsilon Pi Tau*, 8(1). [Chapter 2]
- Kozak, M. R. (1989). Systems approach for technology education: A curriculum delivery system. In F. de Klerk Wolters, I. Mottier, J. Raat, & M. de Vries (Eds.), *Teacher Education For School Technology*, proceedings of the Pupils Attitude Toward Technology (PATT) Conference IV, (pp. 187-197), Eindhoven, The Netherlands, April 13-18, 1989. Eindhoven, The Netherlands: Pedagogical Technological College. [Chapter 7]
- Kuilman, M. (1989). The importance of school technology for industry. In F. de Klerk Wolters, I. Mottier, J. Raat, & M. de Vries (Eds.), *Teacher Education For School Technology*, proceedings of the Pupils Attitude Toward Technology (PATT) Conference IV, (pp. 11-17), Eindhoven, The Netherlands, April 13-18, 1989. Eindhoven, The Netherlands: Pedagogical Technological College. [Prologue]

- Lauda, D. P. (1987). Impact of technology: A travel through time. In M.R. Kozak & J. Robb (Eds.), *Technology Education Symposium IX*, proceedings, (pp. 47-52). Denton, TX: North Texas State University. [Chapter 2]
- Lenski, G., & Lenski, J. (1974). *Human societies*, (NY: McGraw-Hill). Cited in Technology and culture, in E. C. Pytlik, D. P. Lauda, & D. L. Johnson (Eds.), (1985), *Technology, Change and Society*, (revised, pp. 3-10). Worcester, MA: Davis. [Chapter 7]
- Leontief, W., & Duchin, F. (1986). *The future impact of automation on workers*. New York: Oxford University Press. [Chapter 4]
- Levitan, S. (1987). Beyond 'trendy' forecasts: The next 10 years for work. *The Futurist*, 21, 28-32. [Chapter 5]
- Levy, F. (1987). *Dollars and dreams: The changing American income distribution*. New York: Russell Sage Foundation. [Chapter 4]
- Lippman, T. W. (1989, October 12). Seven states inhospitable to nuclear waste. *The Washington Post*, A5. [Chapter 4]
- Loepp, F. (1986). Technological literacy, an educational challenge. In M. Sanders (Ed.), *Technological Literacy: An Educational Mandate*, proceedings of the Technology Education Symposium VIII, October 17-18. Blacksburg, VA: Virginia Polytechnic Institute and State University. [Chapter 6, 7]
- Lund, R. T., & Hansen, J. A. (1983). *Connected machines, disconnected jobs*. Cambridge, MA: M.I.T. Center for Policy Alternatives. [Chapter 5]
- Lux, D. G. (1978) *Youth's need for technological literacy*. Paper presented at the American Industrial Arts Association Annual Conference, Atlanta, GA., February 27 - March 3. [Chapter 7]
- Lux, D. G. (1983, April 23) *Science and technology: A new alliance*. Paper presented at the American Industrial Arts Association Annual Conference, Milwaukee, WI. [Chapter 7]
- Mackie, R. (Ed.). (1981). *Literacy and revolution: The pedagogy of Paulo Freire*. New York: Continuum. [Chapter 7]
- MacPherson, K. (1986, February 17). Education can remove 'magic' from technology. *The Star-Ledger*, Newark, NJ. [Chapter 7]
- Magazine, A. (1989, January 19). Human resources restoring America's competitive edge. *Vital Speeches of the Day*, 502-507. [Chapter 5]
- Malecki, E. J. (1983). Technology and regional development: A survey. *International Regional Science Review*, 8(2), 89-125. [Chapter 4]
- Maley, D. (1981). *Technology education in Europe*. ERIC ED 234 020 [Chapter 3]
- Maley, D. (1987). Issues and trends in technology education. An unpublished manuscript. College Park, MD: Author. [Chapter 2]
- Maley, D. (1987). Technological literacy as a major thrust for technology education. *The Journal of Epsilon Pi Tau*, 13(1), 44-49. [Chapter 8]
- Marchello, J. M. (1987). Education for a technological age. *Futures*, XVIX (5), 555-565. [Chapter 5]
- Margulis, L., & Lovelock, J. E. (1975). The atmosphere as circulatory system of the biosphere—The GAIA Hypothesis. *Co-Evolution Quarterly*. [Chapter 11]
- Mark, J. A. (1987). Technological change and employment: Some results from BLS research. *Monthly Labor Review*, 110(4), 26-29. [Chapter 4]

- Markert, L. R. (1985). *General life satisfaction inventory*. San Jose, CA: Author, San Jose University. [Chapter 7]
- Markert, L. R. (1985). Quality of life in our technological society. *The Journal of Industrial Technology*, 1(4), 6-10. [Chapter 7]
- Markey, J. P., & Parks, W., II. (1989). Occupational change: Pursuing a different kind of work. *Monthly Labor Review*, 112(9), 3-12. [Chapter 4]
- Markusen, A., Hall, P., & Glasmeier, A. (1986). *High tech America: The what, how, where and why of the sunrise industries*. Boston, MA: Allen & Unwin. [Chapter 4]
- Maroyama, M. (n.d.). *Post-industrial logic. The next 25 years: Crisis and opportunity*. Washington, DC: World Future Society. [Chapter 11]
- McCrary, D. (1983, May 5). *Personal communication*. Morgantown, WV: Author. [Chapter 7]
- McLoughlin, P. F. M. (1986, September). A theory of technology—Continuity and change in human development: A review article. *Journal of Economic Issues*, 20(3), 785-798. [Chapter 4]
- Miller, J. D. (1983). *The American people and science policy: The role of public attitudes in the policy process*. New York: Pergamon Press. [Chapter 7]
- Miller, J. D. (1983). Scientific literacy: A conceptual and empirical review. *Daedalus*, 112(2), 29-48. [Chapter 7]
- Miller, J. D. (1986, February 14). *Technological literacy: Some concepts and measures*. A paper presented at the National Conference on Technological Literacy, Baltimore, Maryland. DeKalb, IL: Public Opinion Laboratory, Northern Illinois University. Also in *Bulletin of Science, Technology and Society*, 6(2 & 3), 195-201. (Materials Research Lab., University Park, PA 16802). [Chapter 7, 8]
- Morris, R. B. (Ed.). (1976). *The U. S. Department of Labor history of the American worker*. Washington, DC: U. S. Government Printing Office. [Chapter 5]
- Morrow, S. R. (1988, January). Personal letter to M. James Bensen. St. Paul, MN: Author. [Chapter 6]
- Myers, N. (Ed.). (1984). *GAIA: An atlas of planet management*. Garden City, NY: Anchor Press. [Chapter 2, 11]
- Naisbitt, J. (1982). *Human capital: The profitable investment*. Technology series, No. 19. St. Paul, MN: Control Data Corp. [Chapter 2]
- National Academy of Sciences, National Research Council, and Manufacturing Studies Board. (1986, July). *Toward a new era in manufacturing: The need for a national vision* (Final report). Washington, DC: National Academy Press. [Prologue, Chapter 5, 7]
- National Academy of Sciences. (1984). *High schools and the changing workplace: The employers' view*. Report of the Panel on Secondary School Education for the Changing Workplace, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, Committee on Science, Engineering, and Public Policy. Washington, DC: National Academy Press. [Chapter 7]
- National Alliance of Business. (1986). *Employment policies: Looking to the year 2000*. Washington, DC: Author. [Chapter 5]
- National Center for Education Statistics. (1988). *Digest of Education Statistics, 1988*. Washington, DC: U. S. Department of Education. [Chapter 10]

- National Education Association. (1988, July). Personal communication with M. J. Bensen. Washington, DC: Author. [Chapter 6]
- National Occupational Information Coordinating Committee. (1988, May 24). Long range plan for the National Occupational Information Coordinating Committee: Program years 1987-1991. Washington, DC: Author. [Chapter 4]
- National Science Board Commission on Precollege Education in Science, Mathematics and Technology. (1983). *Educating Americans for the 21st Century*. Report to the American People and the National Science Board. Washington, DC: NSBC, National Science Foundation. [Prologue, Chapter 7, 8]
- National Science Teachers Association. (1982). Science-Technology-Society: Science education for the 1980's. Position statement adopted by the Board of Directors of the NSTA. Washington, DC: Author. [Chapter 1]
- National Study of School Evaluation. (1987). *Evaluative criteria* (6th ed.). Falls Church, VA: Author. [Chapter 9]
- Nee, J. G. (1988). The U.S.S.R.'s development of polytechnic education. *School Shop*, 47(9), 30-31. [Chapter 3]
- Nemec, M. M. (1987). Exclusive interview with U. S. Secretary of Labor William E. Brock: Workforce 2000: Dramatic changes and a shortage of skilled workers. *Industrial Engineering*, XVIX(10), 26-31. [Chapter 5]
- Netzer, D. (1982). Response No. 5. In *The New Liberal Arts: An Exchange of Views*, (pp. 36-38). New York: Alfred P. Sloan Foundation. [Chapter 11]
- New Jersey Bell. (March, 1988). Technology is for everyone. *TelNews*. South Plainfield, NJ: Author. [Prologue]
- New York State Education Department. (1984). *Technology Education Curriculum*. Albany, NY: The University of the State of New York. [Chapter 6]
- New York State Education Department. (1985). *Introduction to technology education: Grades 7 & 8*. Albany, NY: New York State Education Department, Division of Occupational Education Programs. [Chapter 6]
- New York State Education Department. (1987). *Technology education: Public information handbook*. Albany, NY: The University of the State of New York, The State Education Department, Division of Occupational Education Programs. [Chapter 6, 7]
- New York State Education Department. (n.d.) *Introduction to technology - group I* (curriculum guide). Albany, NY: The University of the State of New York, The State Education Department, Division of Occupational Education Programs. [Chapter 7]
- Northwest Regional Education Laboratory. (1984, August). *Technological literacy: Skills everybody should learn. Ideas for action in education and work*. Portland, OR: Oregon Education and Work Program, Northwest Regional Education Lab. ERIC ED 255 729 [Chapter 7]
- Northwest Regional Education Laboratory. (1984). *Technological literacy: What industry can offer. Ideas for action in education and work*. Portland, OR: Oregon Education and Work Program, Northwest Regional Education Lab. [Chapter 7]
- Obey, D., & Sarbanes, P. (Eds.). (1986). *The changing American economy*. New York, NY: Basil Blackwell. [Chapter 4]

- Office of Technology Assessment. (1988). *Power on! New tools for teaching and learning*. Washington, DC: U. S. Government Printing Office. [Prologue]
- Office of Technology Assessment. (1988, May). *Technology and the American economic transition: Choices for the future*. Washington, DC: U. S. Government Printing Office, OTA-TET-283 & 284. [Chapter 4]
- Oklahoma Department of Vocational and Technical Education. (1989). *Program visitation report*. Stillwater, OK: Author. [Chapter 9]
- Oklahoma Department of Vocational and Technical Education. (1989). *Summary evaluation for technology education*. Stillwater, OK: Author. [Chapter 9]
- Olson, D. W. (1963). *Industrial arts and technology*. Englewood Cliffs, NJ: Prentice Hall. [Chapter 1]
- Osterman, P. (1987). Turnover, employment security, and the performance of the firm. In M. M. Kleiner, et al. (Eds.), *Human Resources and the Performance of the Firm*, (pp. 275-317). Madison, WI: Industrial Relations Research Association. [Chapter 4]
- Ouchi, W. G. (1984). *The M-form society: How American teamwork can recapture the competitive edge*. Reading, MA: Addison-Wesley. [Chapter 4]
- Pacey, A. (1983). *The culture of technology*. Cambridge, MA: M.I.T. Press. [Chapter 3, 7]
- Parker, T. (1985). *In one day*. Boston: Houghton Mifflin. [Chapter 2]
- Peckham, S. (1989, September). What is technology education, *School Shop*, 49(2), 15-18. [Chapter 7]
- Pella, M., O'Hearn, G., & Gayle, C. (1966, May). Scientific literacy-Its referents. *The Science Teacher*, 33-44. [Chapter 1]
- Pepper, D. (1984). *The roots of modern environmentalism*. London, UK: Croom Helm. [Chapter 11]
- Perreault, R., & Kozak, M. (1984, May/June). 1984 revisited. *Industrial Education*, 73(5). [Chapter 2]
- Peterson, R. E. (1986). Elementary school technology education programs. In R. E. Jones & J. R. Wright (Eds.), *Implementing Technology Education*, 35th yearbook of the American Council on Industrial Arts Teacher Education, (pp. 47-69). Bloomington, IL: McKnight. [Chapter 2]
- Piore, M. J. (1987). Historical perspectives and the interpretation of unemployment. *Journal of Economic Literature*, 25(4), 1834-1850. [Chapter 4]
- Popenoe, D. (1971). *Sociology*, (NY: Appleton, Century Crofts). Cited in Technology and Culture, in E. C. Pytlik, D. P. Lauda, & D. L. Johnson (Eds.), (1985), *Technology, Change and Society* (revised, pp. 3-10). Worcester, MA: Davis. [Chapter 7]
- Price, R. (1978). *Technological forecasting*. University Park, PA: Pennsylvania State University. [Chapter 7]
- Pullias, D. (1987). 2030 A.D.: Role of the technology education classroom instructor. In M.R. Kozak & J. Robb (Eds.), *Technology Education Symposium IX*, proceedings, (pp. 57-59). Denton, TX: North Texas State University. [Chapter 2]
- Pytlik, E. C., Lauda, D. P., & Johnson, D. L. (1985). *Technology, change and society* (revised). Worcester, MA: Davis. [Prologue, Chapter 2, 7]
- Quinn, J. B., Baruch, J. J., & Paquette, P. C. (1987). Technology in services. *Scientific American*, 257(6), 50-58. [Chapter 4]

- Raat, J. H. (1986). Research in technology education. *PATT Newsletter*, (01), 1. [Chapter 3]
- Raat, J. H. (1987). *Pupil's attitudes towards technology*. Paper presented at the International Technology Education Association Conference, Tulsa, OK, March 23-27. Eindhoven, The Netherlands: Author, Eindhoven University of Technology. [Chapter 6, 7]
- Raat, J. H. (Ed.). (1987). *Report: PATT-conference, Volume 1, Proceedings*, Eindhoven, The Netherlands, April 9-14. Eindhoven, The Netherlands: Eindhoven Technological University. [Chapter 6]
- Raat, J. H. (1987, December). *The increasing importance of technology education as part of general education*. Paper presented to the International Vocational Education and Training Association conference, Las Vegas, NV. Eindhoven, The Netherlands: Author. [Chapter 7]
- Raat, J. H., & de Vries, M. (Eds.). (1986). *What do boys and girls think of technology? Pupils' attitude towards technology*, proceedings, March 6-11. Eindhoven, The Netherlands: Eindhoven University of Technology. [Chapter 3]
- Raspberry, W. (1988, December 12). Too good for manual labor? *Washington Post*. [Chapter 6]
- Raymond, H. A. (1986, September/October). Management in the third wave. *The Futurist*. [Chapter 2]
- Rehg, J. (1986, May). Automation training tools of the future. *Technological Horizons in Education*, 13(9), 78-81. [Chapter 7]
- Richter, J. (1980). The construction and partial validation of a scale to measure technological literacy of communication technology. Doctoral dissertation. West Virginia University. Ann Arbor, MI: University Microfilms International. *Dissertation Abstracts International*, 41112A DDJ81-10609. [Prologue]
- Rifkin, J. (1987). *Time wars: The primary conflict in human history* (1st ed.). New York: H. Holt. [Prologue, Chapter 7]
- Riis, U. (1986). Technology-Now part of the general education in the Swedish comprehensive curriculum. In J. Raat & M. de Vries (Eds.), *What Do Boys and Girls Think of Technology? Pupils' Attitude Towards Technology*, proceedings, [pp. 125-136], March 6-11. Eindhoven, The Netherlands: Eindhoven University of Technology. [Chapter 3]
- Rosenbaum, A. (1988). Vocational education in Italy. *School Shop*, 47(9), 32-35. [Chapter 3]
- Rosenberg, N., & Frischtak, C. (1985). *International technology transfer: Concepts, measures, and comparisons*. New York: Praeger. [Chapter 5]
- Rosenfeld, S. A. (1986, Fall). The education of the renaissance technician: Postsecondary vocational-technical education in the south. *Foresight*, 4(2), 1-27.
- Rosenfeld, S. A. (1988, June 22). Educating for the factories of the future. *Education Week*, 7(39), 48. [Chapter 7]
- Rosenfeld, S. A. (Ed.). (1986). *Technology, the economy, and vocational education*. Research Triangle Park, NC: Southern Growth Policies Board. [Chapter 7]
- Rothman, R. (1986, June 11). 'Scientific Illiteracy' found widespread among adult Americans in new study. *Education Week*, 5(38), 1, 14. [Chapter 7]

- Rothman, R. (1988, January 13). Bennett offers high school's 'ideal' content. *Education Week*, 7(15 & 16), 1, 26-30. [Chapter 7]
- Rothman, R. (1988, September 28). Science-achievement levels on test distressingly low. *Education Week*, 8(4), 1, 11. [Chapter 7]
- Roy, R. (1986). Technological literacy—Clarifying the concept and its relationship to STS. *Bulletin of Science Technology and Society*, 6,(2 & 3), 131-137. [Chapter 1]
- Ruina, E. (1986). In This Issue. *The Weaver*, Council for the Understanding of Technology in Human Affairs, Brown University. [Chapter 6]
- Rutherford, F. J. (1987, November 6). Personal letter to M. James Bensen. Washington, DC: Author. [Chapter 6]
- Ryle, G. (1949). *The concept of mind*. London: Hutchinson's Universal Library. [Chapter 1]
- Sale, K. (1985). *Dwellers in the land: The bioregional vision*. San Francisco, CA: Sierra Club Books. [Chapter 11]
- Scarborough, J. D., & Blankenbaker, E. K. (1983). *Technological literacy: The language dimension*. Monograph. Reston, VA: American Industrial Arts Association. [Chapter 1, 2, 8]
- Schumacher, E. F. (1979). *Good work*. New York: Harper & Row. [Chapter 11]
- Science and Technology Agency. (1985, June 25). Report of the Japanese-U. S. conference on high technology and international environment. *Japan Economic Journal*, 19. [Chapter 5]
- Sculley, J. (1989, February 2). The power of ideas and information. *Vital Speeches of the Day*, 565-569. [Chapter 5]
- Sebaly, K. P. (1988). The evolving role of voc-ed in technological societies. *School Shop*, 47(9), 23-25. [Chapter 3]
- Seidman, S. A., & Kozak, M. R. (1983, Spring). To the year 2033: The impact of high technology on teacher education. *Texas Teacher Education Forum*, 8(1). [Chapter 2]
- Shamos, M. (1963, April). The price of scientific literacy. *NASSP Bulletin*, 47(282), 41-51. [Chapter 1]
- Shanker, A. (1989, January 12). Personal communication with M. J. Bensen. Washington, DC: Author. [Chapter 6]
- Sheets, R. G., & Stevens, D. W. (1989). *Refining the use of market incentives in the public provision of training and related services in the 1990s*. Washington, DC: The National Commission for Employment Policy. [Chapter 4]
- Shemick, J. M. (1985). The perceptual and psychomotor domain: An overview. In J. M. Shemick (Ed.), *Perceptual and Psychomotor Learning in Industrial Arts Education*, 34th Yearbook, American Council for Industrial Arts Teacher Education. Peoria, IL: Bennett & McKnight. [Chapter 2]
- Singer, C. J., Holmyard, E. J., & Hall, A. R. (Eds.). (1954-84). *A history of technology*. Oxford, UK: Clarendon Press. [Chapter 7]
- Skolimowski, H. K. (1966, Summer). The structure of thinking in technology. *Technology and Culture*, 3(3), 371-390. [Chapter 7]
- Slaght, R. L. (1987). We can no longer separate thinkers from doers in the liberal arts. *The Chronicle of Higher Education*. [Chapter 11]
- Smalley, L. (1982). A proposal written to the American Council of Industrial Arts Teacher Education to develop a technological literacy test. University of Wisconsin-Stout, Menomonee, WI. [Chapter 7]

- Smalley, L. (1984). Technology literacy test. Unpublished report supported by a grant from the American Council on Industrial Arts Teacher Education. Menomonie, WI: Author, University of Wisconsin-Stout. [Chapter 7]
- Smalley, L. (1986). Technology literacy test. In M. Sanders (Ed.), *Technological Literacy: An Educational Mandate*, (pp. 53-56). Blacksburg, VA: Virginia Polytechnic Institute and State University. [Prologue, Chapter 1]
- Smalley, L. (n.d.) *Matrix for technology*. Unpublished paper. Menomonie, WI: Author, University of Wisconsin-Stout. [Chapter 7]
- Smalley, L. (n.d.) *Technology — A start*. Unpublished paper. Menomonie, WI: Author, University of Wisconsin-Stout. [Chapter 7]
- Smalley, L. (n.d.). Technological literacy in the primary school. Unpublished report. Menomonie, WI: Author, University of Wisconsin-Stout. [Chapter 7]
- Smalley, L. (n.d.). Technology literacy test-revised. Unpublished report. Menomonie, WI: Author, University of Wisconsin-Stout. [Prologue, Chapter 7]
- Snyder, J. F., & Hales, J. A. (1981). *Jackson's Mill industrial arts curriculum theory*. Charleston, WV: West Virginia Department of Education. [Chapter 1, 2]
- Solow, R. M. (1988). Growth theory and after. *The American Economic Review*, 78(3), 307-317. [Chapter 4]
- Spier, R. F. (1968). Technology and the material culture, in J. A. Clifton (Ed.), *An introduction to cultural anthropology*, (Boston: Houghton Mifflin). Cited in *Technology and Culture*, in E. C. Pytlik, D. P. Lauda, & D. L. Johnson (Eds.), (1985), *Technology, Change and Society*, (revised), (pp. 3-10). Worcester, MA: Davis. [Chapter 7]
- Sredl, H. R. (1988). Educating the Chinese people to further industrial goals. *School Shop*, 47(9), 39-40. [Chapter 3]
- Starr, M. K. (1988). *Global competitiveness: Getting the U.S. back on track*. New York: W. W. Norton [Chapter 10]
- Stern, S., & Matsuda, T. (1988). Japan educates its students in technology and computers. *School Shop*, 47(9), 41-42. [Chapter 3]
- Stevens, D. W. (1987). *The human implications of technological change*. Los Angeles, CA: University of Southern California. [Chapter 4]
- Stevens, D. W. (1989). *The role of vocational education in Missouri's economic development: What can we learn from other states?* Jefferson City, MO: Missouri State Council on Vocational Education. [Chapter 4]
- Streumer, J. N., & Doornekamp, B. J. (1988). *The need for technology education*. Paper presented at annual meeting of the American Educational Research Association, New Orleans, LA. [Chapter 3]
- Taylor, A., & Middleton, H. (1986). Strategies for change. In *Proceedings of the 1986 Technology Teacher Education Forum*. National Committee on Technology Teacher Education. Canberra, Australia: Australian Council for Education through Technology. [Chapter 6]
- Technology Education Advisory Council. (1988). *Technology: A national imperative*. Reston, VA: International Technology Education Association. [Chapter 6, 8]
- Technology Education Division. (1989). *Strategic plan for the division*. Alexandria, VA: TED, American Vocational Association. [Chapter 6]

- Teich, A. H. (Ed.). (1990). *Technology and the future* (5th ed.). New York: St. Martin's Press. [Chapter 5]
- Thomas, J. C. (1987). Technology education: The appropriate threads for a complex tapestry. In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13 -15, (pp. 175-178). Columbus, OH: The Ohio State University. [Chapter 2]
- Thurow, L. G. (1975). *Generating inequality*. New York: Basic Books. [Chapter 4]
- Todd, R. D. (1985). Technology education: An international perspective. In *Technology Education: A perspective on Implementation*, (pp. 19-24). Reston, VA: International Technology Education Association. [Chapter 1, 3]
- Todd, R. D. (1986). Technological literacy: An international perspective. In M. Sanders (Ed.), *Technological Literacy: An Educational Mandate*, (pp. 63-69). Blacksburg, VA: Virginia Polytechnic Institute and State University. [Chapter 1]
- Todd, R. D. (1987). A conceptual basis for a technology education curriculum. In R. C. van den Bergh (Ed.), *Report: PATT-Conference, Volume 2, Contributions*, proceedings, (pp. 388-402), Eindhoven, The Netherlands, April 9-14. Eindhoven, The Netherlands: Eindhoven Technological University. [Chapter 3]
- Todd, R. D. (1987). *New York State technology education: Looking to the future*. Paper presented at the International Technology Education Association Conference, Tulsa, OK, March 23-27. New York: Author, New York University. [Chapter 7]
- Todd, R. D. (1991). The impact and challenge of technological literacy. In M. Dyrenfurth, & M. Kozak (Eds.), *Technological Literacy*. 40th Yearbook, Council on Technology Teacher Education. Peoria, IL: Glencoe/ McGraw-Hill. [Prologue]
- Toffler, A. (1971). *Future shock*. New York: Bantam Books. [Chapter 7]
- Townley, P. (1989, January 27). Business and education reform—lots of action, any impact? *Vital Speeches of the Day*, 354-356. [Chapter 5]
- U. S. Government Printing Office. (1987). *Workforce 2000: Work and workers for the 21st century, Executive summary*. Washington, DC. [Chapter 4]
- Ubell, E. (1961, May). Are you literate about science? *Vogue*, 128. [Chapter 1]
- United Nations Educational, Scientific and Cultural Organization (UNESCO). (1983, July). *Technology education as part of general education: A study based on a survey conducted in 37 countries*. Paris, France: UNESCO. [Chapter 3, 7]
- United Nations Educational, Scientific and Cultural Organization. (1984, November). Final report: Consultation meeting on pilot project "technology in general education." Unpublished report of meeting, Beijing, Peoples Republic of China, April 3-5, 1984. Paris, France: UNESCO, ED-84/WS/86. [Chapter 3, 7]
- United Nations Educational, Scientific and Cultural Organization. (1985, November). Final report: International symposium on the teaching of technology within the context of general education. Unpublished report of meeting, Paris, November 18-22, 1985. Paris, France: UNESCO, ED-85/CONF.809/COL.21. [Chapter 3, 7]

- United Nations Educational, Scientific, and Cultural Organization. (1985). *International symposium on the teaching of technology within the context of general education*. Paris, France: UNESCO. [Chapter 3]
- University of Wisconsin-Stout. (1989). *Better living through technology: Wisconsin at risk*. Report of the steering committee for strategic planning in engineering and technology within the University of Wisconsin System. Madison, WI: University of Wisconsin. [Chapter 6]
- Van Poucke, J., & Wansteenkiste, M. (Eds.). (1985). *The impact of technology on society and education: A comparative perspective*. A publication prepared by the Dutch-speaking Society of Comparative Education as a contribution to the Congress of the Comparative Education Society of Europe. ERIC ED 287 470. [Chapter 3]
- Verein Deutscher Ingenieure. (1977). *VDI-Richtlinie 2222, Konstruktionsmethodik, Konzipieren techn. Produkte*. Berlin und Köln, FRG: Beuth Verlag. [Chapter 7]
- Vocational Technical Education Service. (1988, September). *Technology education for Michigan*. Brochure. Lansing, MI: Michigan Department of Education. [Chapter 7]
- Vohra, F. C. (1988). Technology in the context of school education: General frameworks. In J. Raat, R. C. van den Bergh, F. de Klerk Wolters, & M. de Vries (Eds.), *Basic Principles Of School Technology*, Volume 1, PATT III conference proceedings, (pp. 11-29), Eindhoven, The Netherlands. Eindhoven, The Netherlands: Eindhoven University of Technology. [Chapter 3]
- Waetjen, W. (1989). *Technological problem-solving: A proposal*. Reston, VA: International Technology Education Association. [Chapter 8]
- Waks, L. (1986). Reflections on technological literacy. *Bulletin of Science Technology and Society*, 6,(2 & 3), 331-336. [Chapter 1]
- Walker, R. (1988, September 21). Literacy urged for all students on agriculture. *Education Week*, 8(3), 1, 9. [Chapter 7]
- Warner, W. E., et al. (1965) *A curriculum to reflect technology*. Introduced at the American Industrial Arts Association Annual Conference in 1947. Columbus, OH: Epsilon Pi Tau. [Chapter 1, 6]
- Warner, W. E., Gilbert, H. G., Phillips, K., Lisack, J. P., Klientjes, P. J., Gerbracht, C. J., & Gary, J. E., (1953). *The industrial arts curriculum—Development of a program to reflect American technology*. Reprint. Columbus, OH: Epsilon Pi Tau. [Chapter 1]
- West, P. (1988, September 7). Study says government must lead in advancing school technologies. *Education Week*, 8(1), 1, 9. [Prologue]
- White, S. (1986). *The New Liberal Arts*. New York: Alfred P. Sloan Foundation. [Chapter 1]
- Wiens, A.E. (1987). Technology education in the liberal arts. *The Journal of Epsilon Pi Tau*, 16(23), 13-15. [Chapter 8]
- Williams, C. F., Badrkhan, K. S., & Daggett, W. R. (1985). *Technology for tomorrow*. Cincinnati, OH: South-Western. [Chapter 7]
- Wilson, J., & Moore, A.J. (1989-90, Winter). Writing the knowledge bases for professional education Standard of the NCATE report. *Action in Teacher Education*, XI(4), 48-53. [Chapter 10]

- Wisconsin Department of Public Instruction. (1988). *Guide to curriculum planning in technology education*. Madison, WI: Wisconsin DPI. [Chapter 6]
- Wolffgramm, H. (1978). *Allgemeine technologie*. Leipzig: VEB Fachbuchverlag. [Chapter 7]
- Wright, J. R. (1980, Fall). Technological literacy: A primary goal for industrial arts teacher education. *The Journal of Epsilon Pi Tau*, 6(2), 35-39. [Chapter 1, 8]
- Young, J. (1988, September 28). The commercial challenge to American innovation. *Vital Speeches of the Day*, 112-115. [Chapter 5]
- Young, J. A. (1990). Technology and competitiveness: A key to the economic future of the United States. In A. H. Teich (Ed.), *Technology and the Future*, 5th Edition. New York: St Martin's Press. [Chapter 5]
- Zahler, D., & Zahler, K. A. (1988). *Test your cultural literacy*. New York: Arco. [Chapter 7]

BIBLIOGRAPHY¹

- (1986, February 15). National scores low in technical literacy. *The Los Angeles Times*.
- (1988, September 19). Human capital: The decline of America's workforce, special report, *Business Week*, 100-121.
- (1988, Spring/Summer). Business joins the battle — the "corporate university." *Education Update*, 11(2), 1. Washington, DC: Heritage Foundation.
- (1980). Modern technology: Problem or opportunity. *Daedalus*, 109(1), entire issue.
- (1982). *High technology and high school: Preparing students for California's changing economy*. A perspective on the issues. Sacramento, CA. California Department of Education.
- (1982, September 19). Why our schools are losing the high-tech race. *Los Angeles Herald Examiner*.
- (1983). *Education today for the economy tomorrow*. Denver, CO: Colorado Department of Education.
- (1983). *Investment in people: An update*. Sacramento, CA. California Department of Education.
- (1983, April 19). Technological education today for tomorrow's economy. *Education Colorado*.
- (1987, September). Special report: Manufacturing sector is confident, but needs skilled workers. *Journal of Accountancy*, 46(2), 164.
- (1988). *The bottom line: Basic skills in the workplace*. Washington, DC: U.S. Department of Labor & U. S. Department of Labor.
- (1988). *The forgotten half: Noncollege youth in America*. Final report. Washington, DC: William T. Grant Foundation Commission on Work, Family and Citizenship.
- (1988). *Youth and America's future: The forgotten half: Pathways to success for America's youth and young families*. Washington, DC. The William T. Grant Commission on Work, Family and Citizenship.
- A.T. Kearney, Inc. (1989). *Profile 21*. Dearborn, MI: Society of Manufacturing Engineers.
- Abelson, P. H. (1987, November 13). Continuing education for blue-collar workers. American Association for the Advancement of Science editorial. *Science*, 238(4829), 875.
- Abernathy, W. J., Kim, B., & Knafl, A.M. (1983). *Industrial renaissance: Producing a competitive future for America*. New York: Basic Books.
- Adams, D. L., et al. (1986). Science, technology, and human values: An interdisciplinary approach to science education. *Journal of College Science Teaching*, 15(4), 254-258.
- Adams, J. (1983). *Technology and society*. Stanford, CA: Stanford University.

¹A selected set of resources relevant to the yearbook's topic including some that were edited from direct citation due to space considerations.

- Adams, J. L. (1981). Response 3. In *The New Liberal Arts: An exchange of views*, (pp. 26-31). New York: Alfred P. Sloan Foundation.
- Adler, P. S. (1986). New technologies, new skills. *California Management Journal*.
- Adult Literacy Task Force. (1988). *Countdown 2000: Michigan's action plan for a competitive workforce*. Lansing, MI: Governor's Cabinet Council on Human Investment.
- Agassi, J. (1966). The confusion between science and technology in the standard philosophies of science. *Technology and Culture*, 7(3), 348-366.
- Alfthan, T. (1985). Developing skills for technological change: Some policy issues. *International Labour Review*, 124(5), 817-829.
- Allen, F. (1957). *Technology and social change*. New York: Appleton-Century-Crofts.
- Alster, N. (1989, February 13). What flexible workers can do: Training employees in several jobs can help companies respond to the market faster. *Fortune*, 119(4), 62-66.
- Anderson, S. F. (1984). *Wielding the double-edged sword: Techniques for teaching about technology—related social issues*. Paper presented at the Annual Meeting of the National Council for Social Studies, Washington, D.C.
- Andre, P. (1986). *The evolution of new technology: Work and skills in the service sector*. Paris, France: Centre for Educational Research and Innovation, Organization for Economic Co-Operation and Development.
- Arensberg, C. M., & Niehoff, A. H. (1971). *Introducing social change*, (NY: Aldine-Attherton). Cited in *Technology and culture*, in E. C. Pytlík, D. P. Lauda, & D. L. Johnson (Eds.), (1985), *Technology, change and society*, (revised), (pp. 3-10). Worcester, MA: Davis.
- Ashburn, A. (1986, June). People and automation: Report of the committee on the effective implementation of advanced manufacturing technology, National Research Council, *American Machinist*, 130(6), 97-112.
- Bagshaw, H., & Gordon, T. (1989). *The new National Curriculum in "Design and Technology": Technology education in the context of a nationally mandated curriculum*. Paper presented at the International Technology Education Association conference, Dallas, TX, March 20-23, 1989.
- Bailey, T. (1989, February). *Changes in the nature and structure of work: Implications for employer-sponsored training*. Paper prepared for the Conference on Employer-Sponsored Training, Alexandria VA, December 1-2, 1988. New York, NY: The Institute on Education and the Economy.
- Bailey, T., & Noyelle, T. (1988, May). *New technology and skill formation: Issues and hypotheses*. Technical paper series, # 1. New York, NY: National Center on Education & Employment, Teachers College, Columbia University.
- Balistreri, J. P. (1987, February). *Impacts of technology (Draft)*. Salt Lake City, UT: Utah State Office of Education.
- Bame, C. (1980). *Exploring technology*. Worcester, MA: Davis.
- Bangasser, V., et al. (1984). *An emerging technology curriculum: A model with task listings*. Springfield, IL: Illinois State Board of Education, Department of Adult, Vocational and Technical Education. ERIC ED 246 233.

- Baran, B., & Parsons, C. (1986). *Technology and skill: A literature review*. Unpublished paper prepared for the Carnegie Forum on Education and the Economy, Berkeley Roundtable on the International Economy. Berkeley, CA: Author.
- Barbour, I. (1983). Democracy and expertise in a technological society. *Phi Kappa Phi Journal*, 63, 3-5.
- Barfield, C. E., & Makin, J. H. (Eds.). (1987). Labor adjustment. In *Trade Policy and U. S. Competitiveness*. Washington, DC: American Enterprise Institute for Public Policy.
- Barlow, M. L. (1982, December). General education and vocational education, *Vocational Education*, 21-29.
- Barnes, J. L. (1988a). *The circular theory of problem solving: A technological method*. A paper presented at the Third National Science, Technology and Society Conference on Technological Literacy, Arlington, VA. Ypsilanti, MI: Author, Eastern Michigan University.
- Barnes, J. L. (1989, February). *A framework for technology transfer*. Paper presented at the Eastern Educational Research Association Conference, Savannah, GA. Ypsilanti, MI: Author, Eastern Michigan University.
- Barnes, J. L. (n.d.). Clearing up some of the confusion associated with technology. Unpublished manuscript. Ypsilanti, MI: Author.
- Barnett, H. (1953). *Innovation: Basis of cultural change*. New York: McGraw-Hill.
- Bartel, A., & Lichtenberg, F. (1987, February). The comparative advantage of educated workers in implementing new technology. *Review of Economics and Statistics*, 69(1), 1-11.
- Beaver, D. deB. (1986). Technological literacy, old and new. *Bulletin of Science, Technology and Society*, 6, 229-234.
- Bensen, M. J. (1988). The transition from industrial arts to technology education. In R. S. Brandt (Ed.), *Content of the Curriculum*. Yearbook. Washington, DC: Association for Supervision and Curriculum Development.
- Berg, I. E. (1970). *Education and jobs: The great training robbery*. Boston, MA: Beacon Press.
- Berger, S., Dertouzos, M. L., Lester, R. K., Solow, R. M., & Thurow, L. C. (1989, June). Toward a new industrial America. *Scientific American*, 260(6), 39-47.
- Berkowitz, M., & Kamsor, J. (Eds.). (1985). *Technological literacy and the science curriculum*. Summary report of the Curriculum Conference, Convent Station, NJ., March 27, 1985. Hackensack, NJ: New Jersey Science Supervisors Association, New Jersey Science Teachers Association. ERIC ED 261 883
- Berryman, S. E. (1987, July). *Breaking out of the circle: Rethinking our assumptions about education and the economy*. Occasional paper series, # 2. New York: National Center on Education & Employment, Teachers College, Columbia University.
- Bertalanffy, L. (1969). *General system theory*. New York: Braziller.
- Betz, M., & McGowan, P. (1984). *Appropriate technology: Choice and development*. Durham, NC: Duke University Press.

- Blair, M. (1985, January). Carl Sagan—from "COSMOS" to education—he covers it all. *Electronic Education*, 4(4), 42-43.
- Blankenbaker, E. K. (n.d.). *Technological literacy, What contributions will industrial arts make?* Paper prepared for the National Industrial Arts Advisory Council. Columbus, OH: The Ohio State University.
- Bluestone, M., & Harbrecht, D. A. (1987, October 12/19). Reading, 'riting, 'rithmetic—and now tech ed. *Business Week*, (3021), 114-117.
- Boorstin, D. J. (1978). *The republic of technology: Reflections on our future community*. New York: Harper and Row.
- Bowles, S., & Gintis, H. (1976). *Schooling in capitalist America*. New York: Basic Books.
- Boyer, E. (1986, August/September). Toward the year 2000 and beyond: A community college agenda. *Community, Technical and Junior College Journal*, 57(1), 14-17.
- Brandt, R. S. (Ed.). (1988). *Content of the curriculum*. ASCD Yearbook. Washington, DC: Association for Supervision and Curriculum Development.
- Braverman, H. *Labor and monopoly capital*. New York: Monthly Review Press.
- Bright, J. R. (1978). *Practical technology forecasting: Concepts and exercises*. Austin, TX: Industrial Management Center.
- Bronowski, J. (1974). *The ascent of man*. Boston, MA: Little, Brown & Co.
- Brown, P. (1982, October). Franklin and Marshall College: Scientific inquiry and the college studies program. *The Forum for Liberal Education*, 5(1), 4-5.
- Brown, P. (Ed.). (1982, October). Science literacy for all students. *The Forum for Liberal Education*, 5(1), 19.
- Brown, R. (1988). *Technology literacy in support of systems training*. Technical paper MM88-793. Dearborn, MI: Society for Manufacturing Engineering.
- Brummett, F. (1986, February 19). Testimony in support of Senate Bill #S-1823 and House Bill #H-3102. To strengthen the technological literacy of the Nation through demonstration programs of technology education. Testimony presented at the Hearing for House Committee on Elementary, Secondary, and Adult Education, Washington, DC.
- Bugliarello, G., & Donner, D. B. (Eds.). (1979). *The history of philosophy and technology*. Urbana, IL: University of Illinois Press.
- Bullock, A., & Stallybrass, O. (Eds.). (1978). *The Harper dictionary of modern thought*. New York: Harper & Row.
- Bunge, M. (1966). Technology as applied science. *Technology and Culture*, 7(3), 329-347.
- Bunge, M. (1972). Toward a philosophy of technology. In C. Mitcham & R. Mackey (Eds.), *Philosophy and technology*, (pp. 62-76). New York: Free Press.
- Bureau of Labor Statistics. (1961). The long-range demand for scientific and technical personnel. Prepared for the National Science Foundation. Washington, DC: U. S. Government Printing Office.
- Burnett, J. N. (Ed.). (1984, January). Technology and science: Important distinctions for liberal arts colleges. *Proceedings of the Davidson New Liberal Arts Symposium*, January 19-20, Vol 1.
- Business — Higher Education Forum. (1989). *American potential: Human dimension*. Washington, DC: Author, American Council on Education.

- Butler, E. P., Hahn, A., & Darr, J. (1985). *The literacy-employment equation: Education for tomorrow's jobs*. San Francisco, CA: Far West Laboratory for Educational Research and Development.
- Byrd, E. A. (1973). *How things work: Practical guide for teaching scientific and technical principles*. West Nyack, NY: Parker Pub. Co.
- Calhoun, A., & Finch, C. (1982). Factors influencing the development of vocational-technical education. In M. Aronson (Ed.), *Vocational Education*, (pp. 59-83). Belmont: Wadsworth.
- Cardwell, D. (1972). *Turning points in western technology*. New York: Science History Publications.
- Carlton, R., & Spellman, C. (1978). *Dreams betrayed: Working in the technological age*. Lexington, MA: Lexington Books.
- Carnegie Forum on Education and the Economy—Task Force on Teaching as a Profession. (1986). *A nation prepared: Teachers for the 21st century*. Washington, DC: Author.
- Carnevale, A. P., Gainer, L. J., & Meltzer, A. S. (1988). *Workplace basics: The skills employers want*. Alexandria, VA: American Society for Training and Development.
- Carson, R. (1970). *Silent spring*. Greenwich, CT: Fawcett.
- Chamber of Commerce of the United States. (1985). *Business and education: Partners for the future*. Washington, DC: Author.
- Chamot, D. (1987, Summer). A union perspective on technological change, *Looking Ahead*, 12-17. Washington, DC: National Planning Association.
- Chandler, A. D. (1977). *The visible hand*. Cambridge, MA: Belknap Press.
- Chestnut, H. (1965). *Systems engineering tools*. New York: Wiley.
- Childe, G. (1951). *Man makes himself*. New York: New American Library.
- Collins, P. D. (1987). *Emergence of the technical generalist*. St. Paul, MN: Author.
- Commission on Workforce Quality & Labor Market Efficiency. (1989, September). *Investing in people: A strategy to address America's workforce crisis*. Washington, DC: U. S. Department of Labor.
- Commoner, B. (1974). *The closing circle: nature, man, & technology*. New York: Bantam Books.
- Compton, W. D. (1969). *The interaction of science and technology*. Urbana, IL: University of Illinois Press.
- Corporate Roles in Public Education Project. (1983). *Basic skills in the U. S. workforce*. Center for Public Resources.
- Cowan, R. (1983). *More work for mother*. New York: Basic Books.
- Croft, V.E. (1989). A national study to determine the characteristics of technological literacy for high school graduates. Unpublished doctoral dissertation. Blacksburg, VA: Virginia Polytechnic Institute and State University.
- Cutcliffe, S. (Ed.). (1985, June). *Contemporary critiques of technology*. Working Papers Series No. 3. Bethlehem, PA: Lehigh University.
- Cutcliffe, S. (Ed.). (1985, November). *Technology and harmony with nature*. Working Papers Series No. 4. Bethlehem, PA: Lehigh University.
- Cutcliffe, S. H., & Goldman, S. L. (1985, Winter). Science, technology and the liberal arts: Report on a national conference held at Lehigh University, Bethlehem, PA, April 1-3, 1984. *Science, Technology, and Human Values*, 10(1), 80-87. ERIC ED 247 113.

- Cutcliffe, S. H., et al. (Comp.). (1983, June). *The machine in the university: Sample course syllabi for the history of technology and technology studies*. Bethlehem, PA: Society for the History of Technology, Lehigh University. ERIC ED 243 669.
- Daumas, M. (1970). *A history of technology and invention*. New York: Crown.
- Davis Publications. (1985-86). *Resources in technology* (a series). Worcester, MA: Davis.
- Davis, S. M. (1987, October). *Future perfect*. Reading, MA: Addison-Wesley.
- De Bevoise, W. (1982, Fall). Education and technology: Predicting the needs for the future. *R & D Perspectives*. Eugene, OR: Center for Educational Policy and Management.
- De Bevoise, W. (n.d.). The contribution of education to economic productivity. *Schooling in a Technological Society*. Eugene, OR: ERIC Clearinghouse on Educational Management, College of Education, University of Oregon.
- De Solla Price, D. (1974). *Gears from the Greeks*. Philadelphia, PA: American Philosophical Society.
- de Grazia, S. (1962). *Of time, work and leisure*. New York: Twentieth Century Fund.
- DeBourcy, H. C. (1989, May). Technology literacy training-the ACTT method. *Technological Horizons in Education*, 16(9), 66-69.
- DeCamp, L. S. (1963). *Ancient engineers*. Cambridge, MA: M.I.T. Press.
- Deegan, W. L., & Dale T. (1987, April/May). Toward a 5th generation of community colleges: Seven priorities for action. *Community, Technical and Junior College Journal*, 57(5), 36-40. ERIC EJ 351 303
- Deforge, Y. (Ed.). (1972, May 8). *The teaching of technology*. A symposium report. Strasbourg, France: Committee for General and Technical Education, Council of Europe. ERIC ED 097 517. [Chapter 7]
- Deijsselberg, W. (1988). Teacher training and the concept of technology. In J. Raat, R. C. van den Bergh, F. de Klerk Wolters, & M. de Vries (Eds.), *Basic Principles of School Technology*, Volume 2, PATT III conference proceedings, (pp. 498-507), Eindhoven, The Netherlands. Eindhoven, The Netherlands: Eindhoven University of Technology.
- Department of Education and Science (DES). (1986). *The curriculum from 5 to 16*. London: Her Majesty's Stationery Office.
- Derry, T. K. & Williams, T. I. (1960). *A short history of technology from the earliest times to A.D. 1900*. Oxford, UK: Clarendon Press.
- Dertouzos, M. L., Lester, R. K., Solow, R. M., & M.I.T. Commission on Industrial Productivity. (1989). *Made in America: Regaining the productive edge*. Cambridge, MA: M.I.T. Press.
- DeVore, P. W. (1976). *Technology and the new liberal arts*. Cedar Falls, IA: University of Northern Iowa.
- DeVore, P. W., Maughan, Jr., G.R., & Griscom, W.E. (1979). Influence of technology on industrial arts subject matter. In G. E. Martin (Ed.), *Industrial Arts Education: Retrospect, Prospect*, (pp. 188-216), 28th ACIATE Yearbook. Bloomington, IL: McKnight.
- DeVries, M. J. (1987). What is technology: The concept of technology in secondary education. *Physics and Technology*. Eindhoven, The Netherlands: Eindhoven University of Technology.

- Dewey, J. (1972). Dewey and the vocational education debate. In A. Wirth (Ed.), *Education in the Technological Society*, (pp. 207-217). Scranton, PA: Intext Educational.
- Diderot, D. (1978). *Diderot encyclopedae: The complete illustrations*. New York: Abrams.
- Dorf, R. C. (1974). *Technology and society*. San Francisco, CA: Boyd & Fraser.
- Drengson, A. R. (1982). Four philosophies of technology. *Philosophy Today*, 26(2), 103-117.
- Drucker, P. (1985, March 26). Technological literacy. *New York Times*.
- Durbin, P. T. (1983). Introduction: Some questions for philosophy of technology. In P. T. Durbin & F. Rapp (Eds.), *Philosophy and Technology*, (pp. 1-14). Boston, MA: D. Reidel.
- Durbin, P. T. (1984). Introduction: Conflicting interpretations of technology and society. *Research in Philosophy and Technology*, 7, xi-xxii.
- Durbin, P. T. (Ed.). (1980). *A guide to the culture of science, technology and medicine*. New York: The Free Press.
- Dyrenfurth, M. J. (1981, March). Postsecondary/adult industrial arts education: Technological literacy for a changing world. *VocEd*, 56(2), 48-51. ERIC EJ 239 944.
- Dyrenfurth, M. J. (1983, January/February). The route to technological literacy. *VocEd*, 58(1), 42-44. ERIC EJ 273 891.
- Dyrenfurth, M. J. (1984, October 24). *Technology's razor edge: The price of a shave!* Keynote address, National Association of Industrial Technology annual conference, Warrensburg, Missouri. Columbia, MO: University of Missouri-Columbia.
- Dyrenfurth, M. J. (1987, December 7). *International perspectives on technological literacy*. Paper presented at the Annual conference of the American Vocational Association. Las Vegas, NV., December 4-7. ERIC ED 290 91.
- Dyrenfurth, M. J. (1989, May 4). *Technology in our future: It can't be business as usual!* Paper presented at NSF-funded Automated Manufacturing Technology conference, Ames, Iowa. Columbia, MO: Applied Expertise Associates.
- Dyrenfurth, M. J., & Miller, F. M. (1986, May). *University and private sector roles in human resource development in a technological era*. Paper presented to the World Conference on Education and Technology, British Columbia, Vancouver, Canada.
- Dyrenfurth, M., Custer, R., & Barnes, J. L. (1989). *Manufacturing workforce skills for the future*. Commissioned research paper. Columbia, MO: Applied Expertise Associates.
- Einstein, A., & Infeld, L. (1961). *The evolution of physics the growth of ideas from early concepts to relativity and quanta*. New York: Simon and Schuster.
- Eisenstein, E. L. (1979). *The printing press as an agent of change communications and cultural transformations in early modern Europe*. New York: Cambridge University Press.
- Eliasson, G., & Ryan, P. (1987, November). *The human factor in economic and technological change*. OECD Education Monographs, n30. Paris, France: Organization for Economic Cooperation and Development, #8562
- Ellul, J. (1964). *The technological society*. (J. Williams, Trans.) New York: Alfred A Knopf. (Original work published in 1954)

- Ellul, J. (1980). *The technological system*. (J. Neugroschel, Trans.) New York: Continuum. (Original work published in 1977)
- Emig, J. (1983). *The web of meaning*. Upper Montclair, NJ: Boynton/Cook.
- Employability Skills Task Force. (1988, April 22). *A Michigan employability profile: Report to the Governor's Commission on Jobs and Economic Development*. Lansing, MI: Governor's Commission on Jobs and Economic Development.
- Exxon Education Foundation. (1984). *Science education in the United States: Essential steps for achieving fundamental improvement*. Conference Report, January 17-20, 1984. New York: Author. ERIC ED 247 104.
- Faddis, C., Ashley, W. L., & Abram, R. E. (1982). Preparing for high technology: Strategies for change. (R.N. NCRVE-R&D-Ser-230). (Contract no.300-78-0032). Columbus, OH: Ohio State University. National Center for Research in Vocational Education. ERIC ED 216 168.
- Feibleman, J. K. (1966). Technology as skills. *Technology and Culture*, 7(3), 318-328.
- Feibleman, J. K. (1972). Pure science, applied science and technology: An attempt at definitions. In C. Mitcham & R. Mackey (Eds.), *Philosophy and technology*, (pp. 33-41). New York: Free Press.
- Ferkiss, V. C. (1959). *Technological man: The myth and the reality*. New York: Braziller.
- Florman, S. (1982). Technological literacy: An uneasy victory. *Technology Review*, 85(5), 6+.
- Florman, S. C. (1976). *Existential pleasures of engineering*. New York: St. Martin's Press.
- Flusche, M. (1987). The long road to technological literacy. *Chemtech*, 17(11), 663-665.
- Flynn, P. M. (1985). *The impact of technological change on jobs and workers*. Unpublished manuscript.
- Flynn, P. M. (1989). Introducing new technology into the workplace: The dynamics of technological and organizational change. Background paper 8a. In Commission on Workforce Quality & Labor Market Efficiency, *Investing in People: A strategy to Address America's Workforce Crisis*. Washington, DC: U. S. Department of Labor.
- Forbes, R. J. (1958). *Man the maker; a history of technology and engineering*. New York: Abelard-Schuman.
- Forbes, R. J. (1964). *Studies in ancient technology*. Leiden: E. J. Brill.
- Foster, D. (1988). Technology: Implications for long range planning. *Educational Technology*, 28(4), 7-14.
- Foster, P. R. (1985). The technological change and the revitalization of industrial arts. *The Journal of Epsilon Pi Tau*, 11(1 & 2), 26-29.
- Founders' Weekend. (1984). North county workshop on science, technology and the undergraduate curriculum. *Proceedings of the North County Workshop on Science, Technology, and the Undergraduate Curriculum*, November 9-10. State University of New York, Potsdam College at Potsdam. ERIC ED 266 696.
- Friedman, E. A. (1980). Technological literacy and the liberal arts. *The Forum for Liberal Education*, 3, 1-3. ERIC ED 196 350.

- Friedman, E. A. (1980, December). Technology as an academic discipline. *Engineering Education*, 71(3), 211-216.
- Froehlich, L. (1985, April 1). Source data: Books. A review of "The culture of technology" by Arnold Pacey. *Datamation*.
- Gabor, D. (1970). *Innovations: Scientific, technological, and social*. London, UK: Oxford University Press.
- Gagne, R., & Briggs, L. (1974). *Principles of instructional design*. New York: Holt, Rinehart, & Winston.
- Galbraith, J. K. (1985). *The new industrial state* (4th ed.). Boston: Houghton Mifflin.
- Gallagher, E. J. *A thousand thoughts on technology and human values*. Bethlehem, PA: Department of English, Lehigh University.
- Gentec. (1986). Competency descriptions (Generalized Technology). Developmental draft. Charleston, IL: Eastern Illinois University.
- Gibbons, J. H. (1983). Automation and the workplace: Selected labor, education and training issues. A technical memorandum. Washington, DC: U. S. Office of Technology Assessment.
- Giedion, S. (1948). *Mechanization takes command, a contribution to anonymous history*. New York: Oxford University Press.
- Gilberti, A. (n.d.). Technological literacy. Unpublished class project. Charleston, IL: Author, Eastern Illinois University.
- Gilfillan, S. C. (1970). The sociology of invention: An essay in the social causes, ways, and effects of technic invention, especially as demonstrated historically [sic] in the author's *Inventing the ship*. Cambridge, MA: M.I.T. Press.
- Gill, I. (1988). *Technological change, education, and obsolescence of human capital*. Paper prepared for National Bureau of Economic Research Summer Institute. Chicago, IL: University of Chicago.
- Goldberg, S. (1986). The Sloan Foundation's new liberal arts program. *Change*, 18(2), 14-15.
- Goldberg, S. E., & Strain, C. R. (Eds.). (1987). *Technological change and the transformation of America*. Carbondale, IL: Southern Illinois University Press.
- Goodlad, J. I. (1983). *A place called school*. New York: McGraw Hill.
- Gordon, J. (1988, October). Who is being trained to do what? *Training*, 25(10), 51-60. ERIC EJ 377 152.
- Gourley, F. A. (1987). Assessment of knowledge and skills needed in selected engineering technician fields: Mechanical, manufacturing, industrial. Raleigh, NC: Program Development Services, North Carolina Department of Community Colleges.
- Grayson, L. P. (1986, June). Education and America's industrial future. *Computer*, 19(6), 10-15, 17.
- Greenan, J. P. (1987, December). *Generalizable skills program of research*. Paper presented at AVA conference, St. Louis, MO: Author.
- Greenfield, L. B. (1979, April). Student problem solving. *Engineering Education*, 69(7), 709-712.
- Gruender, C. D. (1971, July). On distinguishing science and technology. *Technology and Culture*, 12(3), 456-463.

- Guilmartin, J. F., Jr. (1974). *Gunpowder and galleys: Changing technology and Mediterranean warfare at sea in the sixteenth century*. New York: Cambridge University Press.
- Habakkuk, H. J. (1962). *American and British technology in the 19th century; the search for labour-saving inventions*. Cambridge, UK: University Press.
- Hacker, M., & Barden, R. (1988). *Living with technology*. Albany, NY: Delmar.
- Hameed, A. (1987). A global model of technological literacy. In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13-15. Columbus, OH: The Ohio State University.
- Harbart, Donald L. (1982, December). Sources and Information. *New Directions for Community Colleges*, pp. 109-118.
- Harman, W. W. (1979). *An incomplete guide to the future*. New York: Norton.
- Harrison, A. J. (1984, February 10). Science, engineering and technology (editorial). *Science*, 223(4636), 543.
- Healy, T. J. (1976). *Energy and society*. San Francisco, CA: Boyd & Fraser.
- Heidegger, M. (1977). *The question concerning technology and other essays*. Translated by W. Lovitt. New York: Harper & Row.
- Heiner, H. (1980). *People create technology*. Worcester, MA: Davis.
- Heritage Foundation. (1988). The workforce literacy movement. *Education Update*, p. 1.
- Herschbach, D. R. (1985). *Linking training and employment: An emerging perspective*. Washington, DC: Bureau for Science and Technology, U. S. Agency for International Development.
- Hersh, R. (1983, May). Are American schools turning out technopeasants? *Instructor*, 92(9), 26-29.
- Hersh, R. (1983, May). How to avoid becoming a nation of technopeasants. *Phi Delta Kappan*, 64(9), 635-638.
- Hewlett, R. G., & Anderson, Jr., O. E. (1962). *A history of the United States Atomic Energy Commission*. University Park, PA: Pennsylvania State University Press.
- Hickman, F. M., et al. (1987). *Science/technology/society: A framework for curriculum reform in secondary school science and social studies*. Boulder, CO: Social Science Education Consortium, Inc.
- Hindle, B. (1981). *Emulation and invention*. New York: New York University Press.
- Hindle, B. (Ed.). (1975). *America's wooden age: Aspects of its early technology*. Tarrytown, NY: Sleepy Hollow Restorations.
- Hofstrand, R. K. (1986). *GenTec*. Springfield, IL: Adult, Vocational and Technical Education, Illinois State Board of Education.
- Hollifield, J. H. (1984). Education and high technology. *Education Digest*, 49(6), 24-25.
- Holly, I. B. (1953). *Ideas and weapons exploitation of the aerial weapon by the United States during World War I; a study in the relationship of technological advance, military doctrine, and the development of weapons*. New Haven, CT: Yale University Press.
- Hounshell, D. A. (1984). *From the American system to mass production 1800-1932: The development of manufacturing technology in the United States*. Baltimore, MD: Johns Hopkins University Press.

- Hubbard, P. H. (1987, February). Tomorrow's workforce. *High Technology*, 7, pp. 10(1)
- Hughes, T. (1987, September). Economic literacy: The power to reward good management. *Production Engineering*, 34(9), 8.
- Hughes, T. P. (1971). *Elmer Sperry; Inventor and engineer*. Baltimore, MD: Johns Hopkins Press.
- Hull, W. L., & Sechler, J. A. (1987). *Adult literacy: Skills for the American workforce*. Columbus, OH: National Center for Research in Vocational Education.
- Hutson, B. A. (1982). *Studying technical literacy in today's society*. Paper presented at the annual meeting of the American Educational Research Association, New York.
- Huxley, A. (1950). *Brave new world: A novel*. London: Chatto & Windus.
- Ihde, D. (1979). *Technics and praxis*. Boston, MA: D. Reidel.
- Ihde, D. (1983). The historical-ontological priority of technology over science. In P. T. Durbin & F. Rapp (Eds.), *Philosophy and Technology*, (pp. 235-252). Boston, MA: D. Reidel.
- Illinois Institute of Technology Research Institute. (1968). *Technology in retrospect and critical events in science*. National Science Foundation Report. Chicago, IL: Author.
- International Business Machines Corporation—Department of Arts and Sciences. (1966). *Leonardo da Vinci: A catalogue of exhibitions of his mechanical inventions*. New York: IBM.
- International Labour Office. (1987). *Training and retraining—implications of technological change*. Geneva, Switzerland: International Labour Office.
- International Technology Education Association. (1989). *Technology education in action*. Reston, VA: ITEA.
- Jenkins, R. V. (1975). *Images and enterprise: Technology and the American photographic industry, 1839 to 1925*. Baltimore, MA: Johns Hopkins University Press.
- Jeremy, D. J. (1981). *Transatlantic industrial revolution: The diffusion of textile technologies between Britain and America, 1790-1830s*. North Andover, MA: Merrimack Valley Textile Museum; Cambridge, MA: M.I.T. Press.
- Jewkes, J., Sawers, D., & Stillerman, R. (1958). *The sources of invention*. New York: St. Martin's Press.
- Johnson, S. D., Foster, W. T., & Satchwell, R. (1989, July). *Sophisticated technology, the workforce, and vocational education*. Springfield, IL: Illinois State Board of Education. DT10730
- Jonas, H. (1979). Toward a philosophy of technology. *Hastings Center Report*, 9(1), 34-43.
- Jungk, R. (1958). *Brighter than a thousand suns: A personal history of the atomic scientists*, (J. Cleugh, Trans.), (1st American ed.). New York: Harcourt Brace.
- Kahn, H., & Weiner, A. J. (1967). *The year 2000: A framework for speculation on the next thirty-three years*. New York: Macmillan.
- Kassom, J. F. (1976). *Civilizing the machine: Technology and republican values in America, 1776-1900*. New York: Grossman.
- Kelty, N. (1987, September/October). Preparing our students for the revolution. *School Leader*, 17(2), 21-23.

- Kidder, T. (1981). *The soul of a new machine* (1st ed.). Boston, MA: Little, Brown.
- Klemm, F. (1964). *A history of western technology*. Translated by D. Waley Singer. Cambridge, MA: M.I.T. Press.
- Koerner, J. D. (Ed.). (1981). *The new liberal arts: An exchange of views*. New York: Alfred P. Sloan Foundation.
- Kowal, J. J. (1987). Technology: The newest liberal art. In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13-15. Columbus, OH: The Ohio State University.
- Kozak, M. R. (1986). *Future choice: Activities not projects*. Paper presented at the American Vocational Association conference, Dallas, Texas, December 7, 1986. Denton, TX: Author, University of North Texas.
- Kranzberg, M. (1964). *Technology and culture: Dimensions for exploration*. Bulletin No. 6. Washington, DC: American Industrial Arts Association.
- Kranzberg, M. (1983, April). Where Were We Going? Where Have We Gone? Statement delivered at the Museum of Science and Industry's Fiftieth Anniversary Conference. Chicago, IL: Author.
- Kranzberg, M. (1987). Technological Literacy: What? Why? For Whom? In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13-15. Columbus, OH: The Ohio State University.
- Kranzberg, M., & Pursell, C. W. (Eds.). (1967). *Technology in western civilization*. Volumes I & II. New York: Oxford University Press.
- Kruger, J. (1987). Science and society programs fuel drive for technological literacy. *Chemical and Engineering News*, 65(8), 25-26.
- Kutscher, R. (1987). The impact of technology on employment in the United States: Past and future. In G. Burke, & R. Rumberger (Eds.), *The Future Impact of Technology on Work and Education*. Philadelphia, PA: The Fullmer Press.
- Landes, D. S. (1969). *The unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the present*. London, UK: Cambridge University Press.
- Landes, D. S. (1983). *Revolution in time: Clocks and the making of the modern world*. Cambridge, MA: Belknap Press of Harvard University.
- Laszlo, E. (Ed.). (1972). *The relevance of general systems theory: Papers presented to Ludwig von Bertalanffy on his seventieth birthday*. New York: Braziller.
- Lauda, D. P. (1989, October). Technology education: Its place in the secondary school. *NASSP Bulletin*, 73(519), 1-3.
- Layton, D. (Ed.). (1984). *The alternative road—the rehabilitation of the practical*. Leeds, UK: Centre for Studies in Science and Mathematics Education, University of Leeds.
- Layton, E. T., Jr. (1973). *Technology and social change*. New York: Harper & Row.
- Layton, E. T., Jr. (1978). Technology as knowledge. *Technology & Culture*, 19(1), 31-41.
- Layton, E. T., Jr. (1986). *The revolt of the engineers: Social responsibility and the American engineering profession*. Baltimore, MD: Johns Hopkins University Press.

- Lenk, H. (1984). Toward a pragmatic social philosophy of technology and the technological intelligentsia. In P. T. Durbin & C. Mitcham (Eds.), *Research in Philosophy & Technology*, 7, 23-58. Greenwich, CT: JAI Press.
- Leontief, W. W. (1986). *Input-output economics* (2nd ed.). New York: Oxford University Press.
- Leontief, W., & Duchin, F. (1984, April). *The impacts of automation on employment, 1963-2000: Abstract and executive summary*. (Final Report) National Science Foundation, Washington, DC. Report No.: NSF/PRA-84002 Contract No.: NSF-PRA80-12844. New York: New York University Institute for Economic Analysis.
- Lerche, R. S., & Nagourney, P. (1989). Education for tomorrow's jobs. Farmington Hills, MI: Lutz Associates.
- Leslie, S. W. (1983). *Boss Kettering: Wizard of General Motors*. New York: Columbia University Press.
- Levin, H. M., & Rumberger, R. W. (1983). The future impact of technology on work skills. In Howard F. Didsbury, Jr. (Ed.), *The World of Work: Careers and the Future*, Bethesda, MD: World Future Society.
- Levin, H. M., & Rumberger, R. W. (1983, December). Secondary education in an age of high technology. *NASSP Bulletin*, 67(467), 49-55.
- Levin, H. M., & Rumberger, R. W. (1985, Summer). Skills, school & technology. *IFG Policy Notes*, 6(2), 1-2. Stanford, CA: Institute for Research on Educational Finance and Governance.
- Lewis, P. A. (1989, March 21). *Technology education: An industry perspective of the new directions*. Unpublished paper presented at the Institute of Industrial Engineers meeting March 21, 1989. Cherry Hill, New Jersey: Public Service Electric & Gas Company.
- Liao, T. T. (1970). *Engineering Concepts Curriculum Project Newsletter*, 4(2). Brooklyn Polytechnic Institute, New York.
- Liao, T. T., & Piel, J. (1970). Toward technological literacy. *EECP Newsletter*, 6(2), 2-4.
- Liao, T. T., Piel, E. J., & Truxal, J. G. (1975). Technology <-> people <-> environment, an activities approach. *School Science and Mathematics*, 75(1), 99-108.
- Lindauer, G., & Hagerty, J. (1984). Technology and society—an upper-level course. *Engineering Education*, 74,(7), 666-668.
- Maclawrin, W. R. (1971). *Invention and innovation in the radio industry*. New York: Arno Press and the New York Times.
- Maley, D. (1985, December). *Implementing technology education in America's schools*. Paper presented at the meeting of the American Vocational Association, Atlanta, GA.
- Maley, D. (1987). Technological literacy: Roles for practical arts and vocational education. In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13-15. Columbus, OH: The Ohio State University.
- Marcuse, H. (1964). *One dimensional man: Studies in the ideology of advanced industrial society*. Boston, MA: Beacon Press.

- Martin, L. (1987). A case for technological literacy. In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13-15. Columbus, OH: The Ohio State University.
- Martino, J. P. (1983). *Technological forecasting for decision making* (2nd ed.). New York: North-Holland.
- Marx, K. (1963). *The Communist manifesto of Karl Marx and Friedrich Engels* (Edited, with an introduction, explanatory notes and appendices by D. Ryazanoff *pseud.). New York: Russell & Russell.
- Marx, L. (1964). *The machine in the garden: Technology and the pastoral ideal in America*. New York: Oxford University Press.
- Maughan, Jr., G. R. (1982, September/October). Computer literacy in the middle school. *Man/Society/Technology*, 42(1), 28-30.
- Mayr, O. (1970). *The origins of feedback control*. Cambridge, MA: M.I.T. Press.
- Mayr, O. (1976). The science-technology relationship as a historiographic problem. *Technology and Culture*, 17(4), 663-673.
- Mayr, O., & Post, R. (1981). *Yankee enterprise: The rise of the American system of Manufacture*. Washington, DC: Smithsonian Institution.
- Mazur, A. (1981). *The dynamics of technical controversy*. Washington, DC: Communications Press.
- McClure, L., & Cotton, K. (Eds.). (1987, November 16-17). *Conference proceedings: Work 4 now and in the future*. Portland, OR: Northwest Regional Educational Laboratory.
- McCullogh, D. G. (1972). *The great bridge*. New York: Simon & Schuster.
- Meadows, D. H., et al. (1974). *The Limits to growth: A report for the Club of Rome's Project on the Predicament of Mankind* (2nd. ed.). New York: Universe Books.
- Melsen, A. G. M. van. (1961). *Science and technology*. Pittsburgh, PA: Duquesne University Press.
- Mesarovic, M. D., & Pestel, E. (1974). *Mankind at the turning point: The second report to the Club of Rome* (1st ed.). New York: Dutton.
- Michalos, A. C. (Ed.). (1974). *Philosophical problems of science and technology*. Boston, MA: Allyn & Bacon.
- Ministère de l'Éducation. (1973). *Initiation à la technologie*. Document 225-210, 889. Quebec, Canada: DGD.P.
- Ministère de l'Éducation. (1979). *Éducation manuelle et technique*. Paris, France: CNDP.
- Ministère de l'Éducation. (1982). *Technologie, classes de seconde, première, et terminale*. Paris, France: CNDP.
- Minnesota Department of Education. (1985). *Minnesota State Guide for Industrial Technology*. St. Paul, MN: Author.
- Misimer, W. C., Jr. (1984, May). Business and industry's role in improving the scientific and technological literacy of America's young. *American Education*, 20(4), 6-9. ERIC EJ 306 512.
- Missimer, W. C., Jr. (1984). Business and industry's role in improving the scientific and technological literacy of America's youth. *Technological Horizons in Education*, 11(5), 89-93.

- Mitcham, C. (1980). Philosophy of Technology. In P. T. Durbin (Ed.), *A guide to the culture of science, technology, and medicine*, (pp. 282-363). New York: Free Press.
- Mitcham, C. (1985). What is the philosophy of technology? *International Philosophical Quarterly*, 25(3), 73-78.
- Mitcham, C., & Mackey, R. (1972). Introduction: Technology as a philosophical problem. In C. Mitcham & R. Mackey (Eds.), *Philosophy and technology*, (pp. 1-31). New York: Free Press.
- Morison, E. E. (1966). *Men, machines and modern times*. Cambridge, MA: M.I.T. Press.
- Morison, E. E. (1974). *From know-how to nowhere: The development of American technology*. New York: Basic Books.
- Moss, J. (1987). Technology education: Subject or student centered. *The Journal of Epsilon Pi Tau*, 13(1), 40-42.
- Mumford, L. (1963). *Technics and civilization*. New York: Harcourt, Brace & World.
- Mumford, L. (1966). Technics and the nature of man. *Technology and Culture*, 7(3), 303-317.
- Murchland, B. (1983, Winter). Technology, liberal learning, and civic purpose. *Liberal Education*, 28(4), 299, 301.
- Mutty, S., & Whipple, L. (1987, January). Minds-on training: Increasing employee involvement. *Production Engineering*, 34, 58-9.
- National Academy of Engineering. (1985). *Education for the manufacturing world of the future*. Washington, DC: National Academy Press.
- National Alliance of Business. (1988). *Shaping tomorrow's workforce*. Washington, DC: Author.
- National Association for Science, Technology and Society. (1989). Brochure. University Park, PA: The Pennsylvania State University.
- National Centre for School Technology. (1973). *School technology forum*. Working paper no. 1. Nottingham, UK: Trent Polytechnic.
- National Centre for School Technology. (1981). *Schools council for modular courses in technology*. Edinburg, Scotland: Oliver & Boyd.
- National Commission on Secondary Vocational Education. (1984). *The unfinished agenda: The role of vocational education in the high school*. Columbus, OH: The Ohio State University, The National Center for Research in Vocational Education.
- New York State Department of Education. (1984, July 18). *Technology education*. Albany, NY: New York State Department of Education.
- Noble, D. F. (1977). *America by design: Science, technology, and the rise of corporate capitalism* (1st ed.). New York: Knopf.
- Noble, D. F. (1984). *Forces of production: A social history of industrial automation* (1st ed.). New York: Knopf.
- Northcutt, N., et al. (1975). *Adult functional competencies: A summary*. Austin, TX: University of Texas Division of Extension.
- Office of Technology Assessment. (1982). *Soviet acquisition of Western technology*. Washington, DC: U. S. Government Printing Office.
- Office of Technology Assessment. (1983). *Technology and East-West trade: An update*. Washington, DC: U. S. Government Printing Office.

- Organization for Economic Cooperation and Development. (1988, May). Social aspects of the new technologies. *MAS/25 Policies for manpower and social affairs*. Paris, France: Author.
- Pacey, A. (1975). *The maze of ingenuity: Ideas and idealism in the development of technology*. New York: Holmes & Meier.
- Page, R., Clarke, R., & Poole, J. (1982). *Problem solving*. Schools Council Modular Courses in Technology Series. Edinburg, UK: Oliver & Boyd.
- Pagels, H. R. (1988, Spring). Computer bashing. Executive director's letter. *Science Focus*, 2(4), 2.
- Perelman, L. (1987, March). *Technology and transformation of schools, Public education strategies for a more competitive nation*. Washington, DC: National School Boards' Association.
- Piel, J., et al. (1970). *The man made world curriculum project*. Stony Brook, NY: State University of New York at Stony Brook.
- Pipho, C. (1989, March 22). Work-force literacy skills. *Education Week*, 8(26), 26.
- Pirsig, R. M. (1974). *Zen and the art of motorcycle maintenance: An inquiry into values*. New York: Morrow.
- Polya, G. (1945). *How to solve it*. Princeton, NJ: Princeton University Press.
- Pratzner, F. C. (1987). Sociotechnical literacy: An alternative to the technological perspective. In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13-15. Columbus, OH: The Ohio State University.
- Price, D. K. (1965). *The scientific estate*. Cambridge, MA: Belknap Press of Harvard University.
- Problem-solving Project Group (McMaster University). (1979, April). Developing style in solving problems. *Engineering Education*, 69(7), 713-717.
- Pytlík, E. C. (n.d.) Great books in technology. Unpublished report of third round delphi study results. Morgantown, WV: Author, West Virginia University.
- Raat, J. H., & de Vries, M. (1985). *Technology as an element of general education: Characteristics and themes of the project physics and technology*. Eindhoven, The Netherlands: Eindhoven University of Technology.
- Rahaman, A. (1981). The interaction between science, technology and society: Historical and comparative perspectives. *International Social Science Journal*, 33, 508-521.
- Ravitch, D., & Finn, C. (1987). *What do our 17-year-olds know? A report on the first national assessment of history and literature*. New York: Harper & Row.
- Reynolds, T. S., et al. (Comp.). (1987). *The machine in the university: Sample course syllabi for the history of technology and technology studies* (2nd ed.). Science, Technology and Society Program, 327 Maginnes Hall #9. Bethlehem, PA: Lehigh University.
- Riis, U. (1986). *Technology and science in school and society: Education, training, subsequent training*. Stockholm, Sweden: National Swedish Board of Education.
- Robertson, A. (1981). Introduction: Technological innovations and their social impacts. *International Social Science Journal*, 33, 431-446.

- Roszak, T. (1972). *Where the wasteland ends: Politics and transcendence in postindustrial society* (1st ed.). Garden City, NY: Doubleday.
- Roy, R. (1982). STS: Core of technological literacy (editorial). *Bulletin of Science, Technology and Society*, 2, 289-290.
- Roy, R. (1983). Technological literacy: An uphill battle. *Technology Review*, 86(8), 18-19.
- Ruina, E. (1982, Winter). *The Weaver*. Cambridge, MA: Massachusetts Institute of Technology.
- Rumberger, R. (1984). *Demystifying high technology*. Columbus, OH: The National Center for Research in Vocational Education.
- Rumberger, R. W., & Levin, H. M. (1989). Schooling for the modern workplace. Background paper 2. In Commission on Workforce Quality & Labor Market Efficiency, *Investing in People: A Strategy to Address America's Workforce Crisis*. Washington, DC: U. S. Department of Labor.
- Rush, R. T., Alden, J. M., & Storlie, R. L. (1986). *Occupational literacy education*. Newark, DE: International Reading Association.
- Rutherford, F. J. (1982, October). Sputnik, Halley's Comet, and science education. *The Forum for Liberal Education*, 5(1), 2-4.
- Sagan, C. (1977). *The dragons of Eden: Speculations on the evolution of human intelligence* (1st ed.). New York: Random House.
- Sagan, C. (1989, September 10). Why we need to understand science. *Parade Magazine*, p. 6-10.
- Sahal, D. (1981). *Patterns of technological innovation*. Reading, MA: Addison-Wesley.
- Sale, K. (1980). *Human scale*. New York: Coward, McCann & Geoghegan.
- Sanders, M. (Ed.). (1986). *Technological literacy: An educational mandate*. Proceedings of the Technology Education Symposium VIII, October 17-18. Blacksburg, VA: Virginia Polytechnic Institute and State University.
- Sarton, G. (1964). *A history of science*. New York: Wiley.
- Savoie, E. J. (1986, September 16). *Creating the workforce of the future: The Ford focus*. Statement submitted to the President's Advisory committee on mediation and conciliation. Dearborn, MI: Employee Development Office, Employee Relations Staff, Ford Motor Company.
- Saxon, D. S. (1982, June). The place of science and technology in the liberal arts curriculum. In *A Report of the Wingspread Conference*, (p. 37). Washington, DC: Association of American Colleges.
- Scarborough, J. D. (1986). A perspective on Japan's general and technical education. *The Technology Teacher*, 45(8), 7-10.
- Schaum, J. H. (1981, June) Our most neglected asset...Human resources. *Modern Casting*, p.39.
- Schmookler, J. (1966). *Invention and economic growth*. Cambridge, MA: Harvard University Press.
- Schon, D. A. (1967). *Technology and change: The new Heraclitus*. New York: Delacorte Press.
- Schools Council. (1966). *Technology and schools*. London: Her Majesty's Stationery Office.
- Schumacher, E. F. (1973). *Small is beautiful: A study of economics as if people mattered*. London: Blond & Briggs.

- Segal, H. P. (1985). *Technological utopianism in American culture*. Chicago: University of Chicago Press.
- Sentance, L. C. (1984). Technological literacy (we can have our cake and eat it too!). *Engineering Digest*, 30(10), 35-38.
- Shamos, M. H. (1984, April 24). *Scientific literacy: Reality or illusion*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA. ERIC ED 244 787.
- Shapiro, R. J. (1987, September 7). The great jobs mismatch. *U.S. News & World Report*, 103, pp. 42(2).
- Shelly, M. W. (1969). *Frankenstein: Or the modern Prometheus* (1831 ed., edited with an introduction by M. K. Joseph). London: Oxford University Press.
- Shen, B.S.P. (1975). Science literacy and the public understanding of science in S.B. Day (Ed.), *Communication of Scientific Information*, (pp. 44-52) Basel Switzerland: Kargel.
- Sherman, S. W. (Ed.). (1983). *Education for tomorrow's jobs*. Washington, DC: National Academy Press.
- Singh, R. R. (1986). *Education in Asia and the Pacific, Retrospect: Prospect*. Bangkok, Thailand: United Nations Educational, Scientific, and Cultural Organization, Regional Office for Education in Asia and the Pacific. ERIC ED 277 494.
- Skagen, A. (Ed.). (1986). *Workplace literacy*. New York: American Management Association.
- Smalley, L. (Ed.). (1981, May 1-2). *Technology Education Symposium II—Technological Literacy*, proceedings. Menomonie, WI: University of Wisconsin-Stout. ERIC ED 206 915.
- Smiles, S. (1905). *Lives of the engineers*. New York: C. Scribner.
- Smith, M. R. (1977). *Harpers Ferry Armory and the new technology: The challenge of change*. Ithaca, NY: Cornell University Press.
- Snow, C. P. (1959). *The two cultures and the scientific revolution*. New York: Cambridge University Press.
- Snyder, D. P. (1987, Spring). Learning for life in revolutionary times: Imperatives for American educators in a decade of techno-economic change. *Journal of Studies in Technical Careers*, 9(2), 91-101.
- Spindler, A. (1974). *Duex ans d'interdisciplinarié*. Sevres, France: Le Centre International d'études pedagogiques de Sevres.
- Sprow, E. E. (1988, March). The training gap. *Tooling & Production*.
- Stashak, G. (1981, May). Technological literacy: The publisher's role. In L. Smalley (Ed.), *Technology Education Symposium II—Technological Literacy*, proceedings. Menomonie, WI: University of Wisconsin-Stout. ERIC ED 206 915.
- Susskind, C. (1973). *Understanding technology*. Baltimore, MA: Johns Hopkins University Press.
- Swyt, D. A. (1986). Technology, industry, skills and education. *The Technology Teacher*, 45(7), 5-9.
- Swyt, D. A. (1986). *The technologies of the third era of the U. S. workforce*. Report to the National Academy of Sciences Panel on Technology and Employment. Washington, DC: National Academy of Sciences.

- Swyt, D. A. (1987, March). *An agenda for progress in technology education: A personal view*. An address to the Plenary Session of the International Technology Education Association International Conference, Tulsa, OK, March 23-27. Gaithersburg, MD: National Bureau of Standards.
- Swyt, D. A. (n.d.). *The factory of the future, its technology and workforce*. Gaithersburg, MD: National Bureau of Standards.
- Tambiah, S. J. (1990). *Magic, science, religion, and the scope of rationality*. Cambridge, UK; New York, NY: Cambridge University Press.
- Technical Foundation of America. (1982). *Industry and technology education: A guide for curriculum designers, implementors, and teachers*. Lansing, IL: Author.
- The Carnegie Foundation. (1983). *High schools - a report on secondary education in America*. New York: Author.
- The Center For Applied Technology. (n.d.). *Technology and labor: The Center For Applied Technology and the Massachusetts AFL-CIO*. Boston, MA: Author.
- The National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Washington, DC: U. S. Department of Education, U. S. Government Printing Office.
- Timmerhaus, K. D. (1987, September/October). Education and science—do we really care? Editorial. *American Scientist*.
- Todd, R. D., McCrory, D., & Todd, K. (1985). *Understanding and using technology*. Worcester, MA: Davis.
- Trachtenberg, A. (1979). *Brooklyn Bridge: Fact and symbol*. Chicago, IL: University of Chicago Press.
- Triangle Coalition for Science and Technology Education. (1988, September). *The present opportunity in education: A position paper on the current state of science and technology education in the United States*. College Park, MD: Author.
- Truxal, J. G. (1986, April). Learning to think like an engineer: Why, what, and how? *Change*, 18(2), 10-19.
- United Nations. (1982). *Control of restrictive practices in transfer of technology transactions*. New York: UN.
- Ure, A. (1967). *The philosophy of manufactures: Or an exposition of the scientific, moral, and commercial economy of the factory system of Great Britain*. New York: A. M. Kelley.
- Usher, A. P. (1954). *A history of mechanical inventions*. Cambridge, MA: Harvard University Press.
- Venn, G. (1963). *Educational implications of technological change*. Detroit, MI: U. S. Department of Health, Education & Welfare, Office of Education. ERIC ED 020 060.
- Wallace, A. F. C. (1978). *Rockdale: The growth of an American village in the early industrial revolution* (1st ed.). New York: Knopf.
- Weiner, N. (1971). *The human use of human beings: Cybernetics and society*. New York: Avon Books.
- Wenk, E., Jr. (1986). *Tradeoffs: Imperatives of choice in a high-tech world*. Baltimore: Johns Hopkins University Press.

- White, C. S. (1987). *The role of the secondary social studies curriculum in developing technological literacy*. Paper presented at the National Science, Technology, Society Technological Literacy Conference, Washington, DC, February 6-8, 1987.
- White, L. T. (1962). *Medieval technology and social change*. Oxford: Clarendon Press.
- White, M. R. (1987). Defining, determining, and contributing to technological literacy: Getting there from here using technology of a research paradigm. In *Technological Literacy: The Roles of Practical Arts and Vocational Education*, international symposium proceedings, May 13-15. Columbus, OH: The Ohio State University.
- William T. Grant Foundation Commission on Work, Family, and Citizenship. (1986). *Time for results: The governors' 1991 report on education*. Washington, DC: National Governors' Association.
- Winner, L. (1977). *Autonomous technology: Technics-out-of-control as a theme in political thought*. Cambridge, MA: M.I.T. Press.
- Winner, L. (1986). *The whale and the reactor: A search for limits in an age of high technology*. Chicago: University of Chicago Press.
- Wolters, F. D., Mottier, I., Raat, J. H., & de Vries, M. (Eds.). (1989). *Teacher education for school technology*, proceedings of the Pupils Attitude Toward Technology Conference (PATT) IV, Eindhoven, The Netherlands, April 13-18, 1989. Eindhoven, The Netherlands: Pedagogical Technological College.
- Yager, R. E. (1984). The major crisis in science education. *School Science and Mathematics*, 84(3), 189-98.
- Yates, B. K., & Dyrenfurth, M. J. (1984, October 24). A question of essentials: Building the necessary base of technological understanding and capability—Technological literacy for Missouri's future. Testimony presented to Missouri State Council on Vocational Education, Springfield, July 26, 1988. Columbia, MO: Author, University of Missouri-Columbia.
- Zuboff, S. (1988). *In the age of the smart machine: The future of work and power*. New York: Basic Books.

Index

A

- Action, versus knowledge and understanding, 16-17
- Advanced Center for Technology Training, Inc. (ACTT), 120, 121
- Advanced Manufacturing Technology (AMT), 87
- Advanced technical courses, 246-47
- Affective development, and technology literacy, 206-7
- Affective domain, 34, 47
- AFL-CIO, 113-14
- Agricultural literacy, 100, 139, 154-55
- AIDS (Acquired Immune Deficiency Syndrome), 106
- American Association for the Advancement of Science (AAAS), 2-3, 5, 123-24, 142, 151
- American competitiveness, causes for decline of, 95
- American Federation of State, County and Municipal Workers, 104
- American Federation of Teachers (AFT), 113, 123
- American Industrial Arts Association (AIAA), 130
- and development of *Curriculum to Reflect Technology*, 20
- development of Professional Improvement Plan, 36
- name change of, to International Technology Education Association, 36
- American Vocational Council, on agricultural literacy, 154
- Amoco Corporation, 112
- Apple Computer, 112
- Applied knowledge, 15
- ARCO, 112
- Argentina, technology literacy in, 59
- Artifacts, 16
- Austria, technology literacy in, 59
- Automatic teller machines, 86
- Automation, in elementary technology education, 195

B

- Barnes, James L., 52, 94-118, 176
- Belgium, technology literacy in, 59
- Bensen, M. James, 52, 151, 176, 177, 239
- Big Bang theory, 28
- Biotechnology, 277-78
- Brazil, technology literacy in, 59

C

- Canada, technology education in, 58, 59
- Cellular communication technology, 83
- Ceramic-matrix composites, 84
- Chamot, Dennis, 52, 151, 176, 177
- Chicago
- case study of technology education, 233-37
- district support activities, 236-37
- evolution of plan, 234
- personnel development, 234-36
- China, technological literacy in, 59, 78
- "City Works" program, in Minneapolis-St. Paul, 134-35
- Cognitive development, and technology literacy, 203-6
- Cognitive domain, 34, 46
- Cohesiveness, building, in technology education, 220-21
- Coleman Report, 140
- Colleges and universities, technology education in, 40-41
- See also Teacher education
- Commission on Industrial Competitiveness, 95
- Commission on the Reorganization of Secondary Education, development of school objectives by, 34
- Communication, impact of technology on, 30
- Communications technology, in elementary technology education, 195-96
- Communications Workers of America, 104
- Competency list approach, to technological literacy, 160-70
- Composites, 30-31
- Computer Integrated Manufacturing (CIM), 87
- Computer literacy, 33, 139
- Computer technology, 29, 221
- in elementary technology education, 194
- Computer tomography, 30
- Construction industry, impact of technology on, 30
- Contingency spending, 91
- Cooper Tire and Rubber Company, 97
- Corporate-educational partnerships, 110, 112-13
- Council for the Understanding of Technology in Human Affairs
- on technological literacy, 126-27
- Council of Europe, 1980
- conference on curriculum trends, 68
- Council on Technology Teacher Education (CTTE), accreditation standards of, 250
- Cuba, technology literacy in, 59
- Cultural literacy, 139

Curriculum models, for technology education, 253-55

Curriculum to Reflect Technology, 20-21

D

Daiber, Robert, 184, 187-211, 239

Dayton-Hudson Corporation, 112

Decisions-by-experts approach to technology education, 262

Democratic society, technological literacy as critical in, 2, 264-65

Demographic facts, and technology literacy, 88-89

Denmark, technology literacy in, 60

Descriptive characteristics approach to technological literacy, 156-60

Design focus, for technology education, 275-76

Deskilling, 102

Developing countries, technology literacy in, 76, 116

DeVore, Paul, 185-86, 251-79

Digital Equipment Corporation, 112

Disciplinary perspectives versus interdisciplinary perspectives, 17-18

Discussion, in assessing technological literacy, 209-10

Doing technology programs, 16-17

Dyrenfurth, Michael, 52-53, 138-86, 208

E

Ecological ethic, 274

Economic Development Commissions, 95

Economic literacy, 139

Economic perspectives on technological literacy, 80-93

Economy, impact of technology for, 32

Education. *See also* Technology education

and ability to think, 35

reassessing focus of, 263

technology as challenge for, 33-35

technology literacy as mandate for, 26-27

Educational Policies Commission,

development of school objectives by, 34

Educational perspectives on

technological literacy, 119-37

of American Association for

Advancement of Science, 123-24

of American Federation of Teachers, 123

community-based education, 134-35

of Council for Understanding of

Technology in Human Affairs, 126-27

educational responses on the international scene, 135

education of workforce, 120-21

engineering education perspective, 133-34

of Humanities and Technology Association, 125

of individual states and councils, 130-31

of International Technology Education Association, 127-29

K-12 perspectives, 131-32

of National Association for Science, Technology and Society, 125

of National Education Association, 123

of Phi Delta Kappa, 122

and the social conscience, 121

teacher education, 132

of Technology Education Division of the

AVA, 129-30

technologically literate society as goal in, 135-37

Egypt, technology literacy in, 60

Electronically enhanced infrared scopes, 30

Electron-beam lithography, 30

Elementary school, 38

technology education in, 188-97

Employee interests, and technology, 84

Enabling ethic, 274

Engineering Concepts Curriculum Project, 160-61

Engineering education perspective on technology education, 133-34

England (United Kingdom)

Craft, Design and Technology programs in, 135

technology literacy in, 60, 67-68

Entrepreneurship, 52

Environment,

impact of technology on, 22, 266-68

Erekson, Thomas L., 52, 94-118, 151

Ethics, 268-274

F

Facility redesign, and technology education, 218-19

Fairchild Aircraft, 112

Fax services, 86

Federal Express, 86

Finland, technology literacy in, 60

First World Assembly on Technology

Education, 36-37

Flexible Manufacturing Systems (FMS), 87

France, technology literacy in, 60

Future ethic, 274

Future technologies, in elementary technology education, 196

G

GAIA hypothesis, 269-70, 279

General Electric, 112

Gene splicing, 84

Georgia Pacific, 112

Germany, technology literacy in, 61-62

Ghana, technology literacy in, 62

Global ethic, 274

Globalization, 54, 96

Government officials,
 technological literacy of, 106
Government perspective on technology literacy
 civil sector, 105-8
 military sector, 108-9
Graphic approach, to technological literacy, 170
Guinea, technology literacy in, 62

H

Hatch, Larry, 185, 239-50
Hewlett-Packard, 97, 112
Holistic focus, on technological literacy, 273
Holmes Group, 241
Home economics program, 14
Honeywell, 112
Human capabilities, future needs for, 109-10
Humanistic ethic, 274
Humanities and Technology Association,
 on technological literacy, 125
Human perceptions, shift in, on Earth, 270
Hungary, technology literacy in, 63

I

IBM, 112
Illinois Plan, 36
 implementation of, in Chicago schools, 234
Image, as problem in technology education,
 219-20
India, technological literacy in, 63, 78
Industrial-scientific paradigm, 268-69
Industry and Technology Education Project, 36
Institutional stress, and technology education,
 83
Instructional technology, 123
Intellectual property, 82
Interdisciplinary perspectives versus
 disciplinary perspectives, 17-18
International Association for Evaluation of
 Educational Achievement on technological
 literacy, 6
International perspectives on technological
 literacy, 54-79
International Technology Education
 Association (ITEA), 36, 130
 on information technology, 176
 on technological literacy, 6, 40, 76-77, 127-29
Intrapreneurship, 52
Italy, technology literacy in, 63

J

Jackson's Mill Industrial Arts Curriculum
 Project, 21, 36, 40, 45, 47
Japan, technological literacy in, 63, 78
Job loss fears, and technology, 102
Jones, Ronald, 185, 239-50
Junior high school. *See* Middle school/
 junior high school

K

Kenya, technological literacy in, 63, 78
Knowledge, versus action, 16-17
Knowledge bases in teacher education,
 241-243, 248-250
Kozak, Michael R., 28-50
Kuwait, technology literacy in, 63

L

Labor market shortages, and technological
 change, 87
Labor sector, perspective of, on technological
 literacy, 94-105
Labor unions, 96-97, 103-5, 113-14, 239
Language development, and technology
 literacy, 203-7
Lasers, in elementary technology education,
 195
Learning, worth of, 265-66
Learning activity packets (LAPs), 218
Learning domains, 34-35
 affective, 34, 47
 cognitive, 34, 46
 psychomotor, 34, 47
Liberal education, proliferation of Science/
 Technology/Science courses in, 15
Literacy
 Canadian definition of, 58
 as component of technological literacy, 15
 definition of, 138-40
 and the new awareness, 270-73
Litherland, Les, 184, 187-211, 239
Lovelock, James E., 269-70

M

Machinists Union, 113-14
Macroeconomics, and public sector choice, 90
Magnetic resonance imaging, 30
Manufacturing, as focus of technological
 progress, 86-87
Market contestability, 90
Market niche, 83-86
Marquis, Lynn, 269-70
Mathematical literacy, 140
Matrix organization, 52
Mauritius, technology literacy in, 64
Meany, George, Center for Labor Studies, 114
Medical technology, 30, 32
Meta-technology, 29, 31
Mexico, technology literacy in, 64
Mid-America Vocational Curriculum
 Consortium (MAVCC), 218
Middle school/junior high school, 38-39
 technology education in, 198-202
Military technology, 108-9
Minneapolis-St. Paul, "City Works" program in,
 134-35
Morocco, technology literacy in, 64

N

- NASA, 112
- National Association for Science, Technology and Society (NASTS), on technological literacy, 125
- National Conference on Technological Literacy, First, 11
- National Council for the Accreditation of Teacher Education (NCATE), accreditation standards of, 250
- National Education Association (NEA), on technological literacy, 123
- National Occupational Information Coordinating Committee, 89
- National Research Council, on agricultural literacy, 154
- National Science Foundation (NSF), on technological literacy, 187
- National Science Teachers Association (NSTA), on technology as component of scientific literacy, 19
- Netherlands, technology literacy in, 64
- New Liberal Arts programs, 3-4, 208
- New York Technology Education Curriculum, 131-32
- Nigeria, technology literacy in, 64

O

- Occupational and Practical Arts Futuring Project (New York State), 36
- Office of Technology Assessment (OTA), 107-8
- Oklahoma technology education, 227-32
- Omnibus Trade and Competiveness Act (1988), 107, 116-17
- Optical fiber technology, 30, 83
- Options, 87
- Organization for Rehabilitation through Training (ORT), 120-21

P

- Package-deal approach to technology education, 214-15
- Pakistan, technology literacy in, 64
- Paper and pencil exercises, in assessing technological literacy, 210
- Paradigm shifts, 268
- Patents, 97
- Phi Delta Kappa, on technological literacy, 122
- Photographic emulsions, 30
- Physiotechnology, 277
- Power on! New Tools for Teaching and Learning* (OTA), 5
- Private sector, perspective of, on technological literacy, 94-105
- Problem solving in technology, 15

- Problem-solving activities, in assessing technological literacy, 210
- Problem-solving model for technology transfer, 110-11
- Problem-solving skills
 - in assessing technological literacy, 209-10
 - in elementary technology education, 194
- Problem-solving strategies, as key to technology education, 190-92
- Productivity, decline of U.S. industrial, 29
- Program monitoring, for technology education programs, 222-24
- Progress, and technology, 266
- Project 2061 (AAAS), 123-24, 142, 151
- Psychomotor domain, 34, 47
- Public interest, in technological literacy, 89-90
- Public schools
 - pressure on, and market niching, 83
 - technology education in, 37
 - for elementary studies, 38, 188-97
 - for high school, 40, 202-9
 - for middle school, 38-39, 198-202
- Pupils' Attitude Toward Technology (PATT) conferences, 4, 37, 135

Q

- Quality circles, 52
- Quality of life, impact of technological illiteracy on, 262-63

R

- Radio telescopes, 30
- Religious pilgrimage, availability of, through technology, 32
- Remote vending facilities, 86
- Research Triangle Institute, 89-90
- Responsibility, and ethics, 271-73
- Robb, Janet, 28-50
- Robotics, in elementary technology education, 195

S

- San Francisco, Exploratorium in, 134
- Scarborough, Jule D., 51, 54-79, 151, 175, 176, 177, 239
- School-based technology education programs.
 - See also* Technology education and assessing technological literacy, 209-10
 - in elementary school, 188-97
 - implementation of, 184, 187-211
 - in middle school/junior high schools, 198-202
 - in senior high school, 202-9
- Schools. *See also* Education obligation of, to teach ability to think, 35
 - purposes of American, 8, 34
- School Shop*, 70

- Science, distinction between technology and, 67, 142
- Science, Technology, and Society programs, 13-14, 41, 208
- integration of, into curriculum, 125
- proliferation of, in liberal arts colleges, 15
- Science for effective citizenship, 18
- Scientific literacy, 11, 140, 154
- dimensions of, 6
- evolution of, 18-19
- technology as component of, 19
- Self-interest, functioning of, and technological change, 87-89
- Semiconductors, 84
- Sensorimotor development, and technology literacy, 206
- Service production, and technological progress, 86
- Sierra Leone, technology literacy in, 64
- Slogan, technological literacy as, 11-12
- Social service, government exploitation of technology in providing, 106-7
- Society, nature of life in, and technology literacy, 2-3
- Solow, Robert, 85
- Southeast Technology Education Association, 130
- Space technology, 31
- Spain, technology literacy in, 64
- Specialization, in technology-related studies, 18
- Sputnik, and evolution of scientific literacy, 18
- Sri Lanka, technology literacy in, 64
- Stacy, Roger, 185, 212-38, 239
- Stevens, David W., 51, 80-93, 151, 177
- Sudan, technology literacy in, 65
- Symposium 80: Technology Education* (Eastern Illinois University), 119
- Syria, technology literacy in, 65
- Systems analysis, 16
- Systems approach, to technology education content, 47-48
- T**
-
- Talking about technology programs, 16-17
- Tanzania, technology literacy in, 65
- Teacher education
- challenge for, 239-50
- growing diversity in, 240-41
- implications of technological literacy for, 185, 239-50
- knowledge bases in, 241
- general studies, 242-43
- knowledge of teaching, 248-49
- pedagogical/clinical knowledge and skills, 249-50
- technical base, 243-48
- state mandates for, 107
- for technology education, 41-45, 132
- professional sequence, 43
- technical sequence, 43-46
- Teamwork, 52
- TECA, corporate contest judges and evaluators, 113
- Technical assistance, providing for technology education programs, 224, 225
- Technical Foundation of America, 36
- Technical means, redirection of, 273-75
- Technological activity, components of, 150
- Technological capability, knowledge in practice through, 25-26
- Technological change, 257
- processes of, 82-84, 87-91
- Technological decision-making, taxonomy of capability for, 24-25
- Technological illiteracy, 261-66
- Technological knowledge, diffusion of, 82-83
- Technological literacy.
- See also specific topics, such as Affective Development.*
- addressing challenge, 275
- ambiguity of term, 11, 13
- assessing, 209-10
- challenges and promises for, 24-27
- chapter author perspectives on, 172
- characteristics of, 7, 70, 159
- as concept, 10, 12-13
- Congressional commitment to, 89
- in context, 8-9, 14-16
- definitions of, 1, 11-14, 71-75, 80, 92, 120, 139-40, 152-53, 177-78, 178-79
- and dehumanization/humanization, 3
- in the design decade, 255
- development of new paradigm in, 7
- as education mandate, 26-27
- evolution of, 8, 10-27, 20-21
- factors influencing development of, 117
- foundation for change in 256-61
- as goal, 6, 13
- government perspective on
- civil sector, 105-8
- military sector, 108-9
- heuristic value of, 13
- implications for, 174-77
- implications for practice, 184-86
- implications for teacher education, 185, 239-50
- importance of, 8, 10, 95
- international development of, 21-22
- international perspectives on, 54-79
- on the job needs for, 103-5
- key perspectives on, 51-53
- knowledge in practice through, 25-26
- literacy as component of, 15, 140
- model of, 179-83

- myths and misconceptions of, 16-22
- nature of, 152-71
- and nature of jobs/competiveness/workforce literacy, 4-5
- and nature of life in society, 2-3
- natures and challenges of, 10-27
- and New Liberal Arts (NLA) directions, 3-4
- "new" versus "old," 75-76
- as program, 13-14
- redirection of technical means, 273-75
- rewards for, 92-93
- significance, importance and justification of, 1-5
- as slogan, 11-12
- social/cultural impacts of, 23-24
- spread of concept of, 75
- synthesized, 138-86
 - meaning and evolution of literacy, 138-40
 - nature of technological literacy, 152-71
 - nature of technology, 140-52
 - and technology as discipline, 5
 - transitioning to new reality, 252-53
 - in the 21st century, 251-52
- Technological literacy model, adaptation of, 208-9
- Technologically literate society, as educational goal, 135-37
- Technologically literate person, characteristics of, 162
- Technological progress
 - characteristics of sustained, 85
 - manufacturing as focus of, 86-87
 - social consequences of, 84
- Technological Systems course, 244-45
- Technology
 - applied knowledge in, 15
 - arenas/fields/systems in, 144-46
 - challenge of, 29-33
 - chapter author perspectives on, 151-52
 - characteristics and processes of, 148-51
 - as component of scientific literacy, 19
 - as component of technological literacy, 15-16
 - context of, 142-44
 - definition of, 13, 14-15, 32-33, 69-70, 146-48, 150-51, 152
 - as a discipline, 5
 - distinction between science and, 67, 142
 - education about. *See* Technology education
 - as educational challenge, 33-35
 - and employee interests, 84
 - and environment, 22, 266-68
 - and ethics, 268-70
 - exponential growth of, 30, 50
 - impact of, on world, 96-97
 - and job loss fears, 102
 - nature of, 140-52
 - organizing study of, 109-15
 - problem solving in, 15
 - and progress, 266
 - talking about, versus doing, 16-17
- Technology Achievement Test development of, 68
- Technology education, 13-14, 207-8.
 - See also* School-based technology education programs; Technological literacy
 - in 21st century, 275-76
 - in Canada, 58
 - central goal of, 184
 - in college and university programs, 40-41
 - curriculum structure for, 46
 - content of, 46-47
 - integrating systems, 49
 - methodology in, 49
 - systems approach of, 47-48
 - in elementary school, 38, 188-97
 - in action, 192-96
 - automation, 195
 - communications technology, 194, 195-96
 - effectiveness of, 189
 - future for, 197
 - future technologies, 196
 - goal of, 197
 - lasers, 195
 - problem-solving skills, 194
 - problem-solving strategies as key, 190-92
 - real versus simulated, 190
 - robotics, 195
 - elements of effective practice, 9, 28-50
 - goal of, 50, 187
 - in high school, 40, 202-9
 - adaptation of the technological literacy model, 208-9
 - approaches to program implementation, 207-8
 - growth and development for technological literacy, 203-7
 - historical developments and influences, 36-37
 - in middle school/junior high school, 38-39
 - activity focus in, 200-2
 - competencies in, 198
 - expansion of, 199-200
 - first course in, 199
 - in year 2050, 200
 - new mission for, 277-79
 - in public schools, 37-40
 - teacher preparation programs, 41-45
 - significance of, 187-88
 - support activities for, 212-38
 - building cohesiveness, 220-21
 - case study of local approach, 233-37
 - case study of state approach, 227-32
 - image in, 219-20
 - insuring continuing input, 221
 - key elements of technology education plans, 217-18

key methodological questions, 218-19
local perspective on, 215-16
monitoring programs, 222-24
program/curriculum development mechanisms, 216-17
providing technical assistance, 224, 225
state perspective on, 214-15
teacher preparation programs for, 41-45
professional sequence, 43
technical sequence, 43-46
as term, 35-36
transition in, 276-77
Technology Education Advisory Council (TEAC)
on breakthrough on technology education, 137
on citizen participation in technology education, 136
on teacher education, 202-3
Technology Education Demonstration Program, 116-17
Technology Education Division of the American Vocational Association on concept of technology literacy, 76-77
technological literacy as goal of, 6
Vocational Association on technological literacy, 129-30
Technology in Society courses, 247-48
Technology literacy training, 120-21
definition of, 121
Technology Student Association, utilization of, for technology education programs, 226
Technology Task Force 2000, 216
Technology teacher education programs.
See Teacher education
Technology transfer problem solving model for, 110, 111
Telescopes, 30
Temporary help agencies, 88
TESA, corporate contest judges and evaluators, 113
Think, ability to, 35
Thode, Terry, 184, 187-211, 239
Tobin, Harry, 185, 212-38, 239
Todd, Ronald D., 10-27, 176
"Tools for Tomorrow" (course), 245
Tunisia, technology literacy in, 65
21st Century Technology Task Force, 216, 227

U

Underemployment, and meta-technology, 29
Understanding versus action, 17
Unemployment, and meta-technology, 29
Unisys Corporation, 98
United Auto Workers, 103
United Kingdom. *See* England
United Nations Educational, Scientific and Cultural Organization (UNESCO)
study of, on technology education, 56-58, 69
United States, technology literacy in, 65
United Steelworkers, 104
Uruguay, technology literacy in, 65
U.S.S.R., technology literacy in, 66

V

Vendor contracting, 88
Venezuela, technology literacy in, 66
Volvo, 102-3

W

White collar workforce, growth of, 96
Wisconsin, technology education in, 131, 133-34
Wisconsin Industrial Education Association, 130
Wisconsin Technology Education Association, 130
Women, utilization of technology by, 31-32
Work, changes in nature of, 102-3
Workers' Technology Bill of Rights, 115
Workforce
and changes in nature of work, 102-3
characteristics of, 97
future needs for human capabilities, 109-10
future needs for skills/competencies, 110
and job loss fears, 102
and on the job needs for technological literacy, 103-5
technological education of, 120-21
trends in, 99-105
Workplace of the future, development of, 52

Z

Zaire, technology literacy in, 66