Instructional Technology

A SYSTEMATIC APPROACH TO EDUCATION

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Kent L. Gustafson

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Library of Congress Cataloging in Publication Data

Knirk, Frederick G.
Instructional technology.

Includes bibliographies and index.
1. Educational technology. I. Gustafson, Kent L.
II. Title.
LB1028.3.K59 1986 371.3'07'8 85-10036

ISBN 0-03-071649-7

Address correspondence to:
383 Madison Avenue
New York, N.Y. 10017

Printed in the United States of America
Published simultaneously in Canada
6 7 8 9 038 9 8 7 6 5 4 3 2 1

CBS COLLEGE PUBLISHING
Holt, Rinehart and Winston
The Dryden Press
Saunders College Publishing

Preface

A quarter-century old, instructional technology (IT) remains an evolving concept as indicated by its many definitions. Its popularity is due in part to its applicability to a wide variety of settings including all levels of education as well as military and industrial training. However, owing to their unique environments, each group of education or training professionals has tended to develop its own definitions and terminology. Even the graduate professional preparation programs differ somewhat in their approaches. Although this diversity is healthy in an evolving field, there has been a tendency to magnify differences rather than identify commonalities.

The primary purpose of *Instructional Technology* is to present the common base of theory and practice associated with IT. From this base, it is then possible to expand in selected areas depending on one's orientation. Both theory and practical tools and techniques are described to illustrate how they may be applied in analyzing, designing, producing, evaluating, implementing, and managing instruction. In the final chapters, readers are alerted to emerging but as yet unproven technologies.

Instructional technology provides a methodological focal point for solving instruction or performance problems. Once a problem has been perceived, it is necessary to collect data to further refine and define it. This analysis may lead to designing and developing an instructional solution. However, it may also lead to alternative solutions such as redesigning the work environment or modifying the psychological climate. For example, redesigning a piece of equipment or changing the motivation or reward structure may, even without additional training, improve performance. It is essential for instructional technologists to keep in mind that application of the analytical procedures associated with IT does not always result in instructional solutions. Basic to the process is allowing data, rather than preconceptions, to dictate the solution.

To apply the IT process, technologists must be competent in many areas including administration, instructional design and development, writing objectives, materials production, research and evaluation, and diffusion of innovative ideas and products. Each of these areas is presented in detail in one or more chapters. However, simply reading about a skill does not make one competent in its application. Readers will find it necessary to practice the procedures and obtain feedback on their efforts.

The format and sequence of the chapters is arranged to reflect an instructional development model. A history of the development of instructional technology and the instructional development model itself are presented in Chapter 1. Chapter 2 illustrates procedures for assessing a problem and determining whether it is even appropriate to apply the balance of the IT process. These needs-assessment and task-analysis procedures are usually the first steps performed in attempting to define and understand the problem. Subsequent chapters examine in detail individual elements of the instructional development model.

We assume the reader has little background in the areas of instructional media, instructional design, administration, or educational psychology. The material has been written at an introductory level but includes extensive references for those desiring to explore topics in greater depth. We view this book as helping you to enter the exciting and challenging world of instructional technology. If it extends your horizon and raises more questions than it answers, it will have served its purpose. The future of IT is far more interesting than its past. We believe it has enormous potential for unleashing the almost untapped creativity and productivity of people.

The application of IT to a wide variety of settings provides a powerful tool for improving the welfare of all. But having said this we must remind ourselves that the current level of practice of IT is really primitive. We have come a long way in twenty-five years, but a long road remains to explore and travel.

Acknowledgments

We would like to gratefully acknowledge the assistance of the graduate students at the University of Georgia and the University of Southern California who have read this text and provided feedback and fresh ideas concerning its development.

The help provided by Dolly Freud, Livia Bachtold, Gina Lashley, Ann Shore, and Susan Pollack is especially appreciated. Their editorial and organizational assistance made this text possible.

To Pat Knirk who typed, edited, and retyped so many times—thank you. And to Elaine Gustafson who always believed in the authors and the ideas—we appreciate your support.

We thank all of these individuals, as well as the following colleagues, for sharing their invaluable skills and resources: Robert K. Branson; Alex Cuthbert, Director of Educational Technology, Washington, D.C.; Fred Pula, Boston College; David Salisbury, Florida State University; Margaret Tossia, Millersville University; Walter Wager, Florida State University; and Thomas C. Wilson, Consultant, Educational Design.

F.G.K./K.L.G.

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Antecedents of Instructional Technology

. . . to be optimally effective, undertake at outset the most comprehensive tasks in the most comprehensive and incisively detailed manner.

Buckminster Fuller

Objectives

After completing this chapter you should be able to:

1. Discuss the learner orientation of instructional technology and contrast it with the teacher orientation of a "teacher aids" media philosophy.
2. List at least ten major developments which have led to the development of an instructional technology.
3. Discuss the history of instructional technology.

Since the 1950s, three main thought streams have been instrumental in creating the field of instructional technology:

1. The concept of designing instruction directly for the student instead of designing audio-visual (A-V) materials for teachers to use in their presentations.
2. Benchmark developments in learning theory as identified by B. F. Skinner, Sidney L. Pressey, N. A. Crowder, and others.
3. The influence of World War II and later the rapidly advancing hardware technology, which required developing quick task analysis procedures, effective training, and new communication technologies; often labeled the "systems approach."

TEACHING OR LEARNING ORIENTATION?

Learning in formal settings has, since time immemorial, been viewed as resulting from teaching. The teacher has been considered both the storehouse of requisite knowledge and the medium of its transmission. While books, and later other media, greatly increased the ability to store information, the teacher remained the primary channel for relaying it to students. However, advances in information storage and retrieval technology have increased both the amount and type of information directly accessible to learners. Interactive systems have added a dimension to information search and utilization that is unparalleled in history. As a result, the teacher's role as both source and medium of information for learners is being modified. We will see an increasing number of teachers leading students to the information, not just transmitting it. Of course, under many circumstances, the information must still be sequenced or arranged to simplify or clarify learning. However, it is becoming more possible for a teacher to make these instructional decisions and store both the knowledge and a structure for acquiring and using it. This trend toward less teacher-dependent learning will not eliminate teachers. Rather, it will increase teachers' roles in curriculum planning, student guidance, and student evaluation while reducing their role as presenters of knowledge.

DEVELOPMENTS IN LEARNING THEORY

The move toward extended learner control of instruction progresses as more becomes known about how people learn. In the 1950s, B. F. Skinner at Harvard University applied stimulus–response (S–R) psychology principles to human instruction. He also developed a procedure for maintaining the required level of performance through reinforcement "schedules." Based on S–R principles, linear-programmed instructional materials were constructed so that a student would almost always provide the correct answer to questions. Skinner's programs were characterized by short, highly structured "frames" of instruction which required students to "construct" their own responses. The student would then immediately be shown the correct response or how to judge its appropriateness. Skinner's work, like most of the significant developments in instructional technology, focused on techniques or methods to increase learning.

Research indicated that stimulus/response-based programs were usually effective for students with similar backgrounds and for definitional or associative level instructional/training objectives. Norman Crowder in the early 1960s, however, thought the programming method could be improved by using principles of Gestalt psychology. Crowder, who was working for the Air Force in training research, felt that other mechanisms could be used to increase learning effectiveness for a greater variety of students and instructional objectives. He developed "intrinsic" programming, which presented larger amounts of information to the learner (up to a full page) before requiring a response. Also, unlike Skinner's linear programs, Crowder's contained multiple-choice responses. After selecting one alternative, the learner was "branched" to a specific next step based on that response. Hence, the term intrinsic, meaning "guided internally" by the learner (or at least the learner's response). Research has indicated that intrinsic programs can effectively teach a variety of types of objectives to a wider range of students.

DEVELOPMENT OF THE SYSTEMS APPROACH

The "systems approach," as applied to teaching and learning, originated in training programs developed by the military. As weapons systems became more complex and required teams of specialized interacting personnel, the armed services sought new procedures for developing and delivering training. The systems approach draws on concepts from general systems theory as well as from information science, communication, learning theory, and other fields. While a variety of systems models was created, all contained three fundamental steps: defining needs; stating instructional objectives; and developing, evaluating, and implementing the instruction. While the systems approach and its elements will be presented in detail later, it is important at this point to keep in mind its relationship to an overall technology of instruction which includes people, processes, and devices.

A HISTORY OF EDUCATION

We turn now to a general historical review of education as it has developed over the ages. From this review it should become clear that instructional technology is not a totally new and different set of concepts. Rather, it is an evolutionary step as people seek to improve their educational enterprise by making it more effective, efficient, and humane.

The invention or development of tools and language created the need for education and training. Word of mouth, demonstration, and limited written records were the primary media for early training. The Greeks found the Socratic method of carefully structuring questions and answers to be effective. This method, which included short organized units of instruction directed toward specific objectives, was tailored to an individual student's interests and abilities. While we reject Socrates' concept that a person's ideas are present at birth, instructional technology is based on many of his tenets. Socrates' students did not take notes, but another Greek, Aristotle, considered notetaking an essential part of the learning process. Both, however, viewed learning as an active and individual process based on objectives and a structured learning environment.

Eventually, a system of providing instruction to individuals through an apprenticeship system developed, which led to grouped instruction processes. This occurred in response to economic pressures when it became desirable to educate a large percentage of the population. Early forms of hardware technology such as chalkboards and books also made grouped instruction feasible.

Thus, over the centuries we have moved from individualized instruction to highly structured organizations providing group instruction.

Apprenticeships in medicine, art, warfare, business, law, masonry, and the like, for direct transmission of information began more than a thousand years B.C. The professions and business communities relied on apprentices for their support and for the continuation of their "trades."

Guilds were formed by people of similar interests for mutual protection and assistance. In this system, which reached its peak in Europe between 1100 and 1500 A.D., the masters and their paid journeymen trained the new apprentices. The regulations on hours, prices, wages, and tools were similar to those found in labor unions today.

Factory schools were established by industries in the United States in the 1800s. They arose because the apprenticeship system did not provide the necessary number of trained people for the factories. Also, because of increasing job specialization workers did not need to be highly skilled at many tasks; they usually had to know how to do only a single operation. Because the workers needed little general education, the training program could be tailored to the specific tasks to be accomplished. During that period, industrial progress was not so rapid that it was necessary to teach principles to permit generalizable understanding and the ability to work in varying or evolving situations.

Elementary and secondary education in the United States was eventually legislated for all children, and it was further legislated that communities be taxed to provide this education at no cost to the student. This decision meant that the skills needed in business and the professions could now be provided by the "public school" system. Children's right to public education now meant that schools had the primary responsibility for their training.

Initially, colleges and universities provided training for only the wealthy in politics, law, religion, and the liberal arts. Vocational training for teachers, farmers, home economists, and industrial workers evolved later because of federal legislation (for example, the Smith-Hughes Act of 1917) and various social pressures. During the early twentieth century much federal money was spent to educate as many adults as would avail themselves of the opportunity.

While economic factors and the shortage of trained teachers once forced abandonment of one-to-one or one-to-a-few instruction in favor of group instruction, advancements in instructional technology are now permitting a return to individualized instruction. The preparation of evaluated and revised instructional materials is initially expensive (like the design of any new product such as cars or computers), but replication of that design for many learners can reduce the cost of individualized instruction or communication to a level comparable with group instruction. The desirability of providing individual programs for learners with different interests, abilities, learning paces, and study habits will be examined throughout this text with discussion and examples. This should not, however, be taken to mean that instructional technology is applicable only to individualized instruction. Instructional technology makes it possible to design and deliver instruction in a wide variety of formats with the decision on group size based on the characteristics of the learner, the type of learning objectives, and the available resources.

In the nineteenth century the Industrial Revolution began with the invention of machines for power and the direction of that power into spinning and weaving on assembly lines. In education, though, the same revolution did not occur, and the technology of instruction remained largely at its preindustrial level. However, during the latter part of the nineteenth century, some materials were designed and mass produced for educators, such as maps, charts, and textbooks. By the beginning of the twentieth century, industrial technology had become well established with plants and factories oriented to assembly lines and interchangeable parts. What the products of mass-production lines lacked in aesthetic appeal was made up for in lower costs, accessibility, and dependability. Henry Ford was able to "produce any color car you desired—as long as it was black." Today, more advanced technology allows even greater diversity and many options in both cars and education.

The U.S. military services have developed many training devices and instructional development procedures that are useful to both public school and training professionals. For example, one of the first blackboards was used at West Point in 1817 by Claude Crozet. Crozet, a Frenchman who spoke poor English, wanted to draw visuals to help overcome his handicap, so he painted a wall of his classroom black and wrote on it with chalk. During World War II, the army bought 55,000 16mm projectors and spent a billion dollars on training films. Their film units developed many of the techniques still used in producing instructional training films. It is reported that Hitler, when asked in 1939 to name the Third Reich's most important new weapon, replied, "my 60,000 motion picture projectors." Following Germany's surrender in 1945, William Kietel, chief of the German General Staff, said, "We had everything calculated perfectly except the speed with which America was able to train its people. Our major miscalculation was in underestimating their quick and complete mastery of film education." (Olsen and Bass, 1982, 33)

The overhead projector was originally called a "viewgraph" by the Navy when it was developed during World War II to improve map briefings and instruction. It was designed to permit the use of previously prepared visuals or allow instructors to face students and use the device as a substitute for a chalkboard. In the mid-1960s the overhead projector began to appear in many nonmilitary classrooms and is now widely used.

The military also supported much of the work of Skinner and Crowder and others who contributed to the development of linear- and branching-programmed instruction techniques. The military language schools also pioneered work on language laboratories. One of the most significant contributions of the military was the development of instructional design models. In 1968 the Department of Defense asked university faculty and industrial trainers for plans for applying a systems approach in the development and management of training courses on a servicewide basis. A demand existed for training programs that would quickly and effectively train many unskilled individuals to operate or

Prehistoric	
	Cave drawings
	Language
Second Century	
	Paper and ink
Fifth Century	
	Block printing
Ninth Century	
	Books
Fifteenth Century	
	Printing from movable type (Gutenberg)
Eighteenth Century	
1793	Use of interchangeable parts (Whitney)
Nineteenth Century	
1837	Telegraph (magnetic) (Morse)
1867	Typewriter (Sholes)
1876	Telephone (Bell)
1878	Transparent film (Eastman)
1879	Incandescent lamp (Edison)

FIGURE 1.1 Educational Technology Milestones and Their Inventors

maintain sophisticated devices—computers, radar units, high-performance aircraft, communications equipment. This demand continues today with the military remaining a significant force in the continual evolution of instructional technology.

In the late 1970s the information revolution began to accelerate due to a societal emphasis on basic research on information processing, artificial intelligence, computers, and advances in publishing technologies. The fruits of this research made possible the generation and dissemination of information at a rate which is now doubling every ten years. Recently, the microchip has allowed average citizens to own their own computers and to directly obtain and manipulate information. For example, programs like Visicalc allow the manipulation of data in a manner and speed never before possible. Access to data banks such as The Source, Dialog, and CompuServe by telephone permits access to encyclopedias and news networks, for example. The information era is certainly

1887	Record, cylinder (Bell)
	Record, disc (Berlinger)
1892	AC motor (Tesla)
1898	Photographic paper (Baekeland)
1899	Wireless telephone (Collins)
Twentieth Century	
1907	Radio tube and amplifier (De Forest)
1909	Mass production techniques (Ford)
1913	Heterodyne radio (Fessenden)
1927	Television (Farnsworth)
	Talking movies (Warner Brothers)
1935	FM radio (Armstrong)
1938	Xerography (Carlson)
1944	Digital computer-automatic (Aiken and others)
1945	Computer memory (Von Neumann)
1946	Electric digital computer (Eckert)
1947	Transistor (Bareen and others)
1948	Cybernetic theory (Weiner)
	Information theory (Shannon)
	LP record (Goldmark)
1954	*The Science of Learning and the Art of Teaching*, Skinner
1962	Communications satellite (Pierce)
1965	NDEA funds for training instructional technologists
1967	Open university planning in Britain
1972	Word processing via computer
1978	Extremely high-speed computer printing
1981	Low-cost personal computer

FIGURE 1.1 (cont.)

upon us. Since teaching is primarily an information-handling profession (transfer of knowledge from "data sources" to receivers with a need for the information), this next decade should be an exciting one for professional educators.

In recent years technology has burgeoned, piling machine upon machine and system upon system, adding fantastically to the control and manipulation of information. Technology has transformed American society, added to its feeling of having a "good life," raised concerns about the ability of various individuals and organizations to obtain "too much" information about an individual, and even modified the fine arts with computer-generated poetry and "painting." And last but not least, it is affecting our educational institution.

Figure 1.1 clearly shows the development of communications hardware, technology, and theory which make possible a comprehensive instructional technology.

During the twentieth century radio, the motion picture, television, computers, and other pieces of communication technology were invented and are now widely used. These media and their accompanying messages are used to create a need for a product or a political candidate, to provide entertainment, or to create educational experiences. American educators, however, have not yet really chosen to use these devices on a large scale in the teaching/learning process.

The development of photographic film and later the transistor, integrated circuits, and the microchip began a technological wave of development which has resulted in less bulky, less expensive, and more reliable training devices. In addition to the book as a medium of instruction, still materials can now be inexpensively presented by slide or microfiche projectors. Motion visuals can be presented using film, videotape, or videodisc equipment. Audio stimuli can be presented alone or with film or videotape equipment in a broad variety of arrangements. The use of computers for instruction now permits educators to store and process an extensive range of data that can be useful in presenting the most desirable sequence of instruction to the learner. While personnel costs have soared, the price of computers has greatly declined. It has been estimated that since 1960, the performance of computers has increased ten thousand times, while the price of "each unit of performance" has declined 100,000 times.

The awesome power of the computer is just beginning to be known by the majority of Americans. You should not find it astonishing when people compare the impact of the computer and microprocessors to that of the Watt steam engine which ushered in the Industrial Revolution more than two hundred years ago. The power of the computer as an information-handling technology will drastically affect formal learning. Indeed, it is already making an impact on learning through "educational toys." Interactive cable systems, satellite communication, lasers, and microstorage devices are also having a profound impact on how information is stored, retrieved, learned, and utilized.

From this brief history of the developments leading to a technology of instruction, we now turn to learning and the development of instruction as two major components of instructional technology.

A TECHNOLOGY OF LEARNING

In the past few decades, developments in learning theory have been remarkable. The development of new information-processing and -transmitting technologies has been multiplying at an ever-increasing rate.

In 1926 at Ohio State University, Sidney L. Pressey developed an early "teaching machine," initially as a test-scoring device which evaluated students' responses and then provided them with the correct responses to the questions. To everyone's amazement, the students learned simply by taking the test.

During that same decade most audio-visual equipment was used as a teacher-aid. Such equipment was usually called audio-visual aids. Some educators began to wonder if direct instruction might be provided by the devices themselves. Could these devices require student involvement by eliciting student responses to questions? Could students be required to answer questions or press buttons to ensure their comprehension before the presentation continued? Could the "programs" be so well designed that the students would generally obtain a challenging and interesting question they would answer correctly and thus be positively reinforced for their learning? These and related questions opened major areas of research on how people learn and how to design effective instruction.

Many research studies were done to compare one approach or medium of instruction with another. Teacher-based systems were usually the referent to which other approaches were compared. The most frequently asked question was, "Did the media work as well as the teacher?" Although some studies favored live teachers and others the mediated approaches, the vast majority of studies resulted in "no significant difference." It is now generally accepted that, for most cognitive objectives, systematically designed mediated presentations will produce about as much learning as a teacher-based system. It is this focus on student learning—and learning principles—rather than on teaching techniques that makes instructional technology stand apart from conventional education and training procedures.

Robert Kilbourn at Wayne State University was the first to change the name of his "audio-visual education" department to "instructional technology." More than just a name change, it reflected a move away from the "aids" concept of assisting teachers to teach and toward the concept of at least some materials being directly used by students without teacher intervention. This philosophy of education was generally championed by James Finn of the University of Southern California, who is usually credited with first defining "instructional technology." Finn was also instrumental in promoting legislation passed by the U.S. Congress in the late 1950s and 1960s that provided funding for research involving instructional technology procedures. Funding also became available for training of instructional technologists through the efforts of Finn and others.

There is a consanguinity between science and technology: advances in learning theory have permitted the development of an instructional technology just as advances in DNA research have resulted in rapidly developing industries using this biogenetic knowledge. Discoveries in management sciences have also resulted in tools useful to educators. Some areas of science that have influenced instructional technology are shown in Figure 1.2.

A TECHNOLOGY OF PROCESS

Complicated problems like designing and manufacturing ships or planning and implementing instruction require handling large amounts of information. The