DOCUMENT RESUME

ED 096 996 IR 001 177

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TITLE	The TICCIT Project: Design Strategy for Educational Innovation. ICUE Technical Report No. 4.
INSTITUTION	Brigham Young Univ., Provo, Utah. Inst. for Computer Uses in Education.
SPONS AGENCY	National Science Foundation, Washington, D.C.
REPORT NO	BYU-ICUE-TR-4
PUB DATE	Sep 73
NOTE	32p.
EDRS PRICE	MF-$0.75 HC-$1.85 PLUS POSTAGE
DESCRIPTORS	*Cable Television; Community Colleges; *Computer Assisted Instruction; Computer Oriented Programs; Computers; Cost Effectiveness; Educational Philosophy; Educational Strategies; *Educational Television; Instructional Design; *Instructional Innovation; Instructional Technology; *Learning Processes
IDENTIFIERS	Brigham Young University; Minicomputers; Mitre Corporation; *TICCIT; University of Texas CAI Laboratory

ABSTRACT

The educational contributions and courseware design strategies which have evolved at Brigham Young University in the course of developing TICCIT (Time-sharing Interactive Computer-Controlled Information Television) are given. The Mitre Corporation and the University of Texas CAI Laboratory also cooperated in this project, which is an advance version of computer-assisted instruction. Discussed is a systems approach to educational goals and needs and the derivation of goals from needs and values. Specified in this report are some parameters of the TICCIT courseware system and the design strategy, learner control, and mastery techniques used by the developers. The roles of students, teachers, and other educators are outlined in the context of the instructional needs in mathematics and English at community colleges. The paper ends with a discussion of effectiveness goals and institutional goals of TICCIT. (WH)

INSTITUTE FOR COMPUTER USES IN EDUCATION

THE TICCIT PROJECT: DESIGN STRATEGY FOR EDUCATIONAL INNOVATION

C. Victor Bunderson

ICUE Technical Report No. 4

September 1973

Sponsored by:
The MITRE Corporation
under NSF Contract #C-179

DIVISION OF INSTRUCTIONAL RESEARCH, DEVELOPMENT & EVALUATION
Brigham Young University
Provo, Utah

ACKNOWLEDGMENTS

C. Victor Bunderson is the Director of the Institute for Computer Uses in Education, Brigham Young University, and co-principal investigator with Kenneth Stetten of the MITRE Corporation on the NSF financed TICCIT project. This paper employs the first-person plural in referring to an interdisciplinary design team who developed the concepts in this paper. This team included at BYU Dr. M. David Merrill, Dr. Gerald Faust, Dr. Harvey Black and the various math and English authors. These individuals contributed from the instructional psychology and content perspectives. Stephen Fine provided a computer science perspective. Among the various graduate students who contributed to the design, Fred O'Neal, Andrew Gibbons, Roy Bennion, and Rowland Blake deserve special mention. Faculty members, project managers and administrators at Northern Virginia Community College and Phoenix College have contributed both to the courseware design and development and to the implementation plan. The courseware and implementation work at BYU is conducted under a subcontract from the MITRE Corporation and NSF contract #C-729. The contributions of Kenneth Stetten, John Volk, John K. Summers, Ned Burr, Paul Neuwirth and others at MITRE to the educational considerations discussed in this paper are difficult to measure, but very real.

THE TICCIT PROJECT: DESIGN STRATEGY FOR EDUCATIONAL INNOVATION

C. Victor Bunderson
Brigham Young University
September 1973

The term TICCIT refers to the MITRE Corporation's "Time-shared Interactive Computer-Controlled Information Television," a hardware concept employing conventional television and cable technologies and minicomputers. Being derived from a hardware description, the term does not signal what we at Brigham Young University regard as the educational contributions of the project. The purpose of this paper is to place the hardware contributions of the MITRE Corporation in context with the educational contributions and courseware design strategies which have been evolving at Brigham Young University and to show how these strategies apply to the needs and goals of the project, including those of teaching community college English and mathematics more productively.

Experience in conference presentations, workshops and visitor orientation to the TICCIT project has proved to be difficult in conveying all of the essential features of this project to a new audience. The TICCIT project is not just another computer-assisted instruction (CAI) project; it is a hopeful but radical departure. Those familiar with existing CAI projects may be deceived when they attempt to apply familiar generalizations about hardware, CAI languages, tutorial, drill, stimulation and other instructional strategies and utilization models to TICCIT--for most of them do not apply. Those who have seen samples of "learner control" must be prepared to redefine their understanding of this concept when discussing TICCIT. Taken alone, each innovation in hardware, software, courseware and implementation seems simple and natural enough. However, one must perceive all of these facets, working in harmony toward educational goals, to understand all of this "elephant," rather than like the blind men, some discrete part of it.

Some History of the TICCIT Project

If TICCIT is indeed different, it is different because of the disciplined design approach to the solution of educational problems and the interdisciplinary cross-fertilization between the designers and developers at three institutions, the MITRE Corporation, the University of Texas CAI Laboratory and Brigham Young University (BYU). The systems engineers and computer scientists at the not-for-profit MITRE Corporation provided the know-how in hardware and software development and integration. Unlike a manufacturer of existing hardware, MITRE was not bound by the constraints of an existing product line. Education for too long has had to make do with computer products designed for business and science and willingly marketed to educators as an instructional tool despite the inappropriateness of the hardware and software capabilities. Unlike a laboratory at a single university, the systems engineers at MITRE are experienced at the process of working backward from a problem to be solved in society at large, to a concrete solution and seeing this solution all the way through to system integration, installation and testing in a real-world environment.

Aware of its own educational and social-science limitations, MITRE looked elsewhere for partners to specify educational goals and strategies. The University of Texas CAI Laboratory, one of the older and more successful of its kind, contributed a learner control philosophy and an educational design science approach. This included the identification of needs, the specification of goals and the development of cost-effective CAI programs (courseware). A hybrid approach was employed which fell somewhere between the disciplines of computer science and educational psychology. The Instructional Research and Development Department at BYU also contributed greatly to this design science approach and contributed a perspective that media hardware must be clearly a function of instructional strategy, and that old models of CAI, developed on yesterday's slightly adopted business or scientific computer systems, may not teach effectively. The graduate program in Instructional Psychology at BYU provided a cadre of trained developers, researchers and theorists who ultimately contributed major theorems of instruction on which the novel design of learner-controlled courseware was based. Most of the key personnel from Texas moved to BYU in 1972 to consolidate the courseware project, effecting a mitosis of the Texas CAI Lab and transplanting it at BYU as the Institute for Computer Uses in Education.

This paper takes the perspective held by members of this interdisciplinary group of instructional psychologists, computer scientists, and others who have gathered to the mountains at Brigham Young University. Since its establishment in 1972, the Institute for Computer Uses in Education (ICUE) has become a department in the new Instructional Research, Development, and Evaluation Division (IRDE). This division is one part of perhaps the largest educational technology group assembled at any major university. A sister Production Services Division provides production facilities in motion picture, television and any of the conventional sorts of media. A third sister division includes the library and learning resource centers. Computer-assisted instruction (CAI) is the newest addition to BYU's learning resources capability. In addition to ICUE, the IRDE division houses instructional evaluation, research and development activities not tied to any kind of media. The Department of Instructional Development is headed by Dr. Edward Green. The Department of Instructional Evaluation and Testing is headed by Dr. Adrian VanMondfrans. Collectively, these departments are organized under an administration at the equivalent level of Dean by Dr. R. Irwin Goodman. These three departments add a research and development focus to the more conventional production activities of the educational technology operations of BYU. Research is enhanced by a graduate program in instructional psychology, in cooperation with the College of Education. Dr. M. David Merrill heads this department.

One result of the rich selection of possible media and methods and the instructional research and theory behind their use is that we place our group clearly in that camp which believes that instruction can be approached as a design science and that the form of the hardware and software, not just the courseware, is a result of that design science approach.

The design science approach to education now evolving at BYU and elsewhere attempts to apply discipline within each of the following stages of design:

1. Analysis of Educational Needs

2. Specification of Project Goals (based on needs and values)

3. Design Strategies

    Instructional Systems Design
    Courseware, Hardware, Software
    Organizational Design (Roles for Teachers and Others)
    Evaluation Design

4. Realization of Designs in Hardware, Software, Courseware and an Organization of People and Machines

5. Subsystem Integration and Testing (for TICCIT, evaluation and revision of hardware, software and courseware occurs at BYU during 1974)

6. System Integration and Testing (for TICCIT demonstration and evaluation occurs at Phoenix College and Alexandria, Virginia, campus of Northern Virginia Community College, 1974-1976)

This paper is organized into three sections according to the first of the six stages of the design process listed above.

ANALYSIS OF EDUCATIONAL NEEDS

Few educators now believe the idealized model of the "systems approach" which asserts that the process of innovation design begins with an analysis of needs in society, narrowing to needs or problems in some class of educational institution, then deriving goals from needs. This rational, ideal model can only be approximated in real life. Actually, a project like TICCIT begins when certain individuals become convinced that computer-assisted instruction (CAI) has tremendous potential to restructure and improve education. These individuals are able to formulate a plan which is logically related to some real needs and are able to obtain resources to evolve and test that plan. Extensive research on

CAI was conducted at many CAI laboratories and centers, in universities, government, industry and schools. By 1970 this work had established by data and argument that CAI could be extremely effective, efficient and motivating, and that its cost could become quite competitive. The National Science Foundation's Office of Computer Innovations in Education, guided by the advice of experts, invested $10 million, starting in 1971-72, in two major demonstrations of CAI. One of these, the PLATO project at the University of Illinois uses a giant computer with upwards of 1,000 student terminals of completely new design. Their approach is to provide teachers with this resource, leaving it up to the users to develop the instructional designs and organizational designs. No attempt is made to restructure the roles of teachers in any major way. By contrast, the TICCIT project uses state-of-the-art computer and television technology. The hardware consists of two minicomputers and 128 color TV student terminals. The hardware, software and courseware are reflections of a strategy for restructuring education toward a learner-centered, individualized model. Men and machines are organized to serve as a source of help for students who are learning and growing in a number of dimensions. The concept is that computers cannot merely be added as an adjunct to teachers in present educational structures, but that a larger redesign must be undertaken. In the words of Peter Drucker:

> The educators still talk of minor changes, of adjustments and improvements. Few of them see much reason for radical changes. Yet education will in all likelihood be transformed within the next decades by giant forces from without.
>
> It will be changed, first, because it is headed straight into a major economic crisis. It is not that we cannot afford the high costs of education; we cannot afford its low productivity. We must get results from the tremendous investment we are making. . .
>
> Teaching is where agriculture was around 1750, when it took some 200 men on the farm to feed one nonfarmer in the town. We have to make the teacher more productive, have to multiply his impact, have to increase greatly the harvest from his or her skill, knowledge, dedication, and effort . . . (P. F. Drucker, The Age of Discontinuity, New York: Harper & Row, 1969).

Given a vision of what can be accomplished and the resources and opportunity to do it, a needs analysis is the application of discipline in data collection and rational analysis to guide broad design decisions, rather than the process of inscribing focus and direction on a blank tablet.

The data collected had to focus on the following questions: Is higher education the most strategic sector of education for the initial introduction of a CAI system designed for major positive educational impact and mass dissemination? Within higher education are the community colleges the sector which initially can best be served by systems like TICCIT? Will they prove more receptive to this type of innovation? Are the costs associated with various kinds of instruction in community colleges high enough that certain of them could be replaced by CAI? What courses have the heaviest load of students, and the greatest need for individualization and deeper levels of remediation? What are the socially and educationally valid motives and aspirations of teachers and other educators which must be served in a system wherein old roles are changed? What are the needs of students which must be served by a man-machine system involving CAI?

Some data and analysis bearing on these questions is documented elsewhere. For this overview, it is suffic to observe that higher education does have high costs, high volume and students who are free to take or leave CAI. It is suffering from serious financial problems and social pressures which call for rapid and dramatic change. Within higher education, community colleges are the most rapidly growing sector. They are dedicated to teaching students and to new forms of community service, not graduate research, and are fairly receptive to innovative approaches to accomplish these goals.

Within community colleges, instruction in Freshman and developmental mathematics and English usually accounts for at least 25 percent of the total contact hours of instruction. A large portion of this (about 80 percent) could be served by two modular systems of CAI lessons in math and English covering from 12 to 25 credit hours of instruction, depending on how these lessons are allocated to course titles. Educational costs in community colleges average $3.26 per student hour, $1.50 in direct instructional costs. Much of this cost could potentially be replaced by a man-machine CAI system with greater effectiveness and a potentially lower cost.

Community college students share with other students the desire for instruction which is relevant to their needs and interests and respectful of their time. They resent phoniness, lack of preparation and arbitrary treatment on the part of teachers. On the other hand, they value productive human interactions with teachers and other students and few would like all college instruction mediated solely by a machine. Open enrollment policies of community colleges introduce large numbers of students who are inadequately prepared in basic math and English skills and thus are unready to take Freshman-level courses in these subjects, or other college courses which depend on these skills. Besides their achievement difficiencies, many suffer from attitudes of avoidance toward study and learning, poor study habits and attitudes that place the blame on others for not teaching them, rather than on themselves as the responsible agents for personal growth.

The motives of teachers are varied. The better ones are rewarded by seeing intellectual and personal growth in individual students, by learning and producing scholarship themselves and by perfecting their teac[illegible] skills. Those who love their subject matter believe they can convey some o[illegible] imponderable values of a liberal education--a reverence for knowledge and [illegible]killful expression, an excitement in its pursuit, an aesthetic delight in th[illegible] [illegible]legant, attractive nuances of a subject, a discipline in problem solving or scholarship. Teachers seek fair recompense for their labors. They value the respect of their students, peers and administrators and community. Not all teachers are good teachers and not all motives for staying in the teaching profession are as laudatory as those just mentioned. A man-machine system involving CAI should enhance the stature, influence and opportunities of teachers possessed of educationally constructive motives and attitudes. It is probable that CAI can only be a small influence in this regard, but it should certainly be designed to be a positive, rather than a negative, influence.

SPECIFICATION OF PROJECT GOALS

Earlier publications on the TICCIT project emphasized the cost aspects of computer-assisted instruction. A panel of NSF advisors, familiar with CAI and other forms of educational technology, had advised that if TICCIT could be no more effective than traditional forms of instruction and could deliver this instruction at less cost, it would be a major contribution. A general goal of the project was then and still is to create a "market success" so that after the application of government funds, private industry will provide efficient dissemination and competition to further drive the cost down.

Despite the more limited aspirations initially held by outside advisors, the design science approach of the TICCIT project started with a set of educational goals that put cost in its proper context. Initially, little could be said about goals which seemed too remote to be accomplished. As the project evolved, however, design strategies became well defined. These strategies now provide basis for optimism that a more ambitious set of goals can be achieved. That complete set of goals is discussed below.

THE DERIVATION OF GOALS FROM NEEDS AND VALUES

In classical statements of the systematic approach to instructional development, goals are derived from the needs of the institutions and the needs of individuals served by these institutions. Preferably these goals are measurable at least through a longitudinal research study. It is clear to any thinking person that this model of the systems approach is an oversimplification. Goals are derived as much from the philosophy and values of the system's designers as from the needs they serve. The needs must be there, it is true, or the product of a design effort will not be used. The goals should indeed be assessable to assure they are achieved.

It is the explicit recognition and use of human goals and values, however, in a rigorous, empirically based process of design and development that provides the critical distinction between a design science and a natural science. Herbert Simon, in his little book of provocative essays on "The Sciences of the Artificial", makes this distinction. While he does not treat the design of instruction directly as one of the artificial sciences, he deals with learning and problem solving in this manner. It is clear from his book that he would consider education as one of those disciplines which could more profitably be viewed from the perspective of artificial science than as a natural science-based field. We prefer the term "Design Science of Instruction" to Simon's term. It would be presumptuous to claim that we have developed a design science for instruction at this time, but it is appropriate to place the designers of the TICCIT courseware within that world-wide group of researchers who believe that such a science can be developed.

There is a diversity in values among the design group which generated learner-controlled courseware. Religious backgrounds include Catholic and Protestant, Mormon and Jewish and a variety of degrees of orthodoxy. Yet there is a core of common values regarding the nature of man and in particular, the roles of students and teachers. Rather than the mechanistic "O" (Organism) of behavioral psychology, we see students as agents, using that meaning of the term which identifies the student as one who acts and who has the power to originate action. The student's own goals and values shape his choice of actions and any description of his choice behavior must be incomplete and deceptive without consideration of these constructs. It is felt that students grow when given responsibility for their own choices and that a system which deprives them of choice limits growth.

Limits to intellectual and personal growth, for all practical purposes, are imposed by the teachings of the student's culture. His genetic inheritance provides broad limits within which growth may occur, and with different degrees of rapidity. Educational institutions are now structured both to unfold human potential along certain dimensions and to limit it in others. Treating this assumption as a value which shapes instructional systems design rather than as an hypothesis to be weighted by the descriptive methods adapted from natural science has strong operational consequences. If the limits to growth are indeed far beyond what can be attained by present educational environments, then the designers of new learning environments can expect quite remarkable quantum leaps in student growth as better and better designs are found.

Any design for a new learning environment can include teachers only, or both teachers and machines. Except in rather limited aspects of a total curriculum, instruction completely by machine-student interaction must be incomplete and probably largely unacceptable by students. Since the majority of a student's life is involved in human interactions and education seeks to expand his ability to function with others, the process of education as a total concept must involve human interactions as its dominant feature. The computer is another technological tool to enhance certain aspects of this process, those aspects which deal with information transmission and processing and information management.

A teacher can be both hero and villain, sometimes both, in the process of bringing about growth in students. A teacher can destroy a student's faith in himself and turn him away from learning forever, or break through barriers that limit his horizon and free him to growth. Teachers can learn to use computers and other tools to expand their ability to instruct, to manage, to build students and to produce scholarship. They can also subvert systems which involve technology and quietly but effectively sabotage the potential of such systems. Some proposed roles for teachers who will use systems like TICCIT are described below.

While we are considering the values which influence the design of TICCIT, it is sufficient to say that the same values related to the process and limits of growth apply to teachers as well as students. Teachers are the central agents in this process, and upon the way they define their roles depends the success of the project and the future of technology in existing educational systems.

No attempt has been made to annotate the above discussion of values from the more than extensive literature of philosophy, psychology and theology. No excellence in these fields is claimed by the designers of the TICCIT courseware, only recognition of the powerful role of values in the process of design. Given the decisive role of values in the design of systems like TICCIT, having great social potential, it would seem that a responsibility exists to make at least the more influential values explicit. Those mentioned above will be seen by the reader to be implicit in the multiple goals for students and the goals for educators discussed below.

DESIGN GOALS FOR TICCIT COURSEWARE, HARDWARE, SOFTWARE & IMPLEMENTATION

Table 1 summarizes the design goals. It will be seen that they are grouped into the categories of institution, content, individual student and educator.

TABLE 1

COURSEWARE DESIGN GOALS

COST GOAL

$1.00 per contact hour
25% less time
Increase enrollment significantly

CONTENT GOAL

Small step forward in content
Clarify objectives
Design for flexibility

TABLE 1, CONT.

GOALS FOR STUDENTS

85% of students will achieve mastery
Increased efficiencies
Improved strategies
Voluntary approach, reduced avoidance
Responsibility

GOALS FOR EDUCATION

Define new roles in management-advisement
Stimulate teachers to demonstrate humane values in follow-on or coordinate instruction
Define new professional roles in development
Instructional research--computer as a tool

INSTITUTIONAL - LEVEL GOALS

A. Cost Goals: It is difficult to include costs of instructors in a cost estimate, since the courseware's flexibility permits such wide variations in faculty staffing. The users must select a cost target themselves, and vary faculty/student ratio and faculty/peer proctor ratio as they see fit. We can project "system costs" to include hardware, software, courseware, computer support personnel, and maintenance. The goal is to keep these costs less than $1.00/hour.

Reduced contact time can become an important cost factor. It is our goal to reduce the time it now takes a student to complete equivalent work in mathematics or English by some 25 percent or more.

B. Enrollment Goals: It is our goal to increase enrollment significantly. The quantitative definition of the word "significantly" is to be determined by the Educational Testing Service through its summative evaluation of the TICCIT project. We expect this increase to occur both through reducing attrition in the college as a whole and through increasing enrollment in courses given by computer-assisted instruction. If achieved, this factor could give administrators an option other than reducing staff to achieve the cost advantages of TICCIT.

C. Content Goals: It was not out goal initially to innovate substantially in curriculum content. We sought an appropriate and accurate representation of the curriculum as now described by professional organizations in the fields of mathematics and English, in textbooks and as taught at community colleges.

As the project has evolved, we have found the math content to correspond closely to standard textbook topics. In order to achieve the more important effectiveness goals, the English content has had to depart more substantially from conventional approaches.

We seek a small step forward in mathematics content through encouraging colleges to combine beginning and intermediate Algebra into one modular system of instructional materials, and to replace the College Algebra, Trigonometry, and Analytic Geometry sequence by the "Math O Course" as recommended by the committee on the undergraduate programs in mathematics. In the Math O approach the student learns the concept of function and sees it illustrated by the various elementary functions.

We seek a larger step forward in English grammar and composition, primarily through moving toward a generative approach to composition, and through clarifying the objectives and structure of those subjects around an internally consistent, generative rhetoric. Our analysis of the objectives of English composition and grammar leads to an apparent simplification in what "topics" are considered. Such an analysis does not map as readily into English textbook topics as does the mathematics analysis.

We expect to provide great flexibility through a modular structure in both mathematics and English so that community college administrators and faculties can utilize these materials in a variety of ways.

EFFECTIVENESS GOALS FOR INDIVIDUAL STUDENTS

A. Mastery: At least 85 percent of the students who take the TICCIT courses will achieve mastery, as defined by the mastery tests at the lesson and unit levels.

B. Efficiency: Students will improve their efficiency in learning from CAI by a substantial factor as measured between the first two and last two units of any course. We now have no good basis on which to make a quantitative prediction for the magnitude of efficiency increases. It stands as a design goal nonetheless, and is expected to contribute to the decreased time of 25 percent or greater discussed above. Time saving is of value to students, as well as to an educational system.

C.. Improved Learning Strategies: Learning strategies are defined operationally in terms of patterns of use of the learner control command language described in another section below. Improvement in strategies will be measured by the extent to which the student's efficiency improves simultaneously with the reduction in his requirement for advice.

D. Approach Rather Than Avoidances: The students will develop a positive attitude of approach rather than avoidance relative to the subject matter in any TICCIT course. Attitude is measured in part by questionnaires given to the student from time to time, but is measured primarily by the extent to which the student will voluntarily work on optional material. This includes AB level materials which are not required, and games, simulations, "tidbits" and other items which are not required. Approach can be measured in a gross way by the extent to which students who take the Algebra course go on and take the higher level course. This assumes that they would not otherwise have taken it. The same type of measurement can take place in English and can be reflected at a gross level through increased enrollment in the more advanced English courses not taught by TICCIT.

E. Responsibility: Students' attitude of responsibility towards learning will increase from the first unit to the last unit. While difficult to measure, it is expected that the extent to which students meet scheduled appointments can be assessed, as can the extent to which they exert continual effort toward achieving goals of mastery and efficiency.

The effectiveness goals for students are very much a function of the learner-controlled courseware concept described below. Rather than being led step-by-step, guided by some all-knowing mathematical algorithm which makes decisions for him, a student is given a command language which allows him to survey freely, establish his own sequence within the constraints set by prerequisites and establish his own learning tactics. Learning tactics are described in terms of the sequence of rules, examples and practice instances a student sees. It is only through this learner-controlled courseware strategy that we hope to be able to help the student achieve improvement in all five of the effectiveness goals discussed above.

GOALS FOR EDUCATORS

A long-range goal of this project is to make a modest contribution toward the enhancement of the profession of education toward greater rigor and discipline, in the application of empirically testable principles of instruction and management. Increased productivity and increased professionalism is the key. The basis for new hope lies in further development of a design science foundation for education and a related technology of instruction. Computers are a principal tool to administer, manage, and design instruction and to collect data relative to prescriptive design theorems.

New roles for teachers and modifications of old ones must emerge before these long-range goals can be achieved. Four which are of special interest to the TICCIT project are the following:

1. Manager-advisors for students involved in TICCIT courses and other technologically mediated systems.

2. Master teachers.

3. Designers and developers of courseware.

4. Instructional Researchers.

Rather than elaborate on these roles in this section, they will be discussed in the section on design strategy after context is provided by a description of the hardware and courseware design.

STRATEGIES TO MEET DESIGN GOALS

Since the hardware and software design for TICCIT is so heavily influenced by the courseware, which in turn is designed toward the effectiveness goals described above, the strategy for achieving the effectiveness goals will be discussed first, followed by a discussion of new roles for educators. There will follow a description of the hardware design to meet the cost goals.

MASTERY

The strategy to achieve the goal of student mastery is based on the application of instructional theorems to the design of a modular courseware data structure. This data structure, or content structure, is separated both conceptually and physically in the computer from the logic which implements instructional sequencing strategies. Instructional sequencing strategies are largely left in the hands of the student, who is guided by an advisor program to develop his own characteristic strategy and tactics.

The instructional research, and the propositions or theorems derived from it, which shaped the design of the content components is described in Merrill and Boutwell (1973) and Merrill (1973). In the former paper, a review of the literature on learning and instruction led to the development of what is in effect a taxonomy of instructional variables. By means of this taxonomy, any instructional sequence involved in complex cognitive learning tasks may be characterized.

This taxonomy involves three classes of variables: presentation form, inter-display relationships and mathemagenic information.

Presentation form may be of four types, generalities or instances, either of which may be presented either in expository or inquisitory form. The system deals primarily with concept learning and rule using, so a generality is a definition of a concept, of a clear statement of a rule. An instance is an example or non-example of a concept or a rule in use. Expository means to tell, inquisitory to ask. Inquisitory generalities (e.g., "define a concept") are rarely used in TICCIT, since memorization of rules is not sought and since it is difficult to analyze by computer open-ended definitions or rule statements in natural language.

Mathemagenic information is information which gives birth (gen-) to learning (mathema-). This category involves prompting and cuing and other attention-focusing techniques. Specific techniques include attribute isolation (use of color, graphics, etc., to highlight key attributes), search strategies (step-by-step algorithm), mnemonic aids, and production strategies (heuristics to guide the production of student-generated products, for example, written paragraphs).

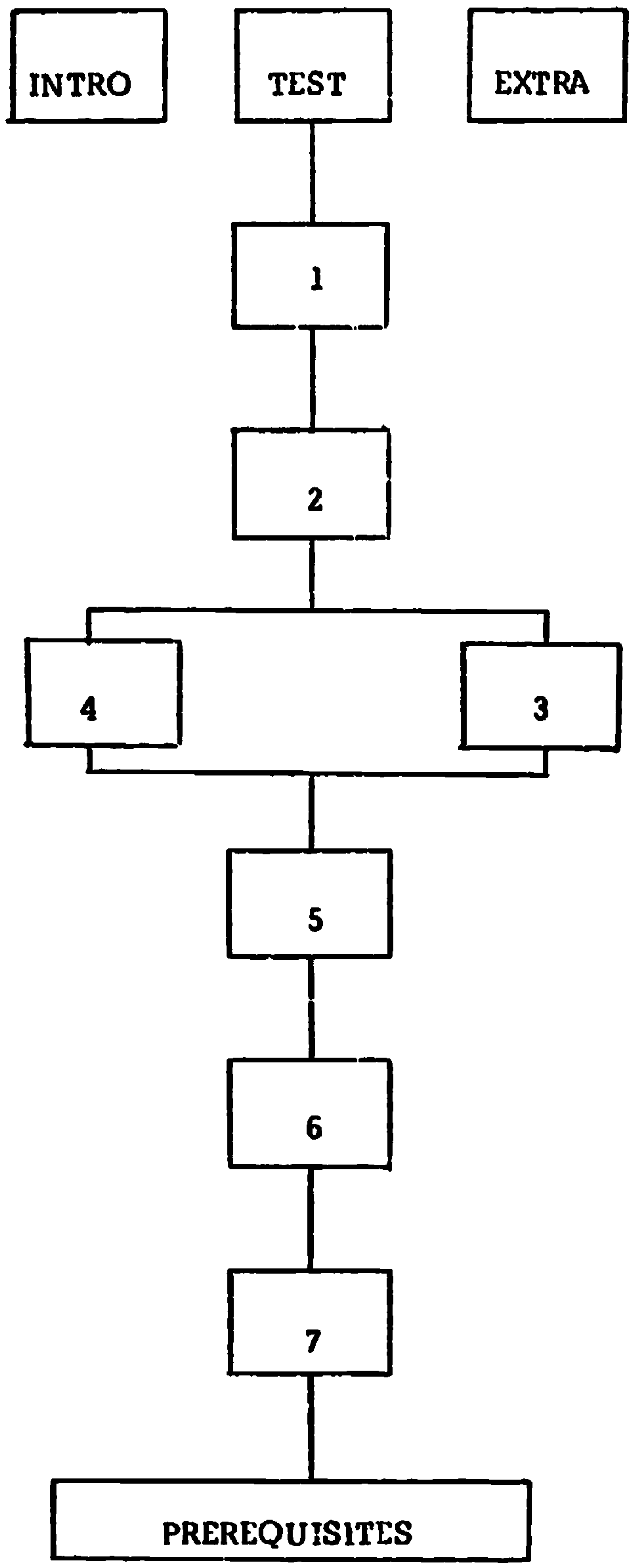
Certain concepts of man-machine instruction developed at the Texas laboratory were combined with the Merrill taxonomy to devise the modular courseware structure. These included the concept of hierarchically indexed data structures and a command language to move about within these structures. A set of content files indexed within these structures was defined. Since the content files were developed along the lines of the taxonomy of instructional variables, the idea was that students could use the command language to sequence these files themselves, thus manipulating instructional variables.

The TICCIT courseware is hierarchically organized into four levels. These levels are represented to the student by special displays that present the hierarchies, list the topics, provide access to a standardized version of the objectives and display status after the student has worked. These are:

Course Level:	Course objectives and status display (course map).
Unit Level:	Unit objectives and status display (unit map).
Lesson Level:	Lesson objectives and status display (lesson map).
Segment Level:	Primary Instruction Components (rule, example, practice).

OBJECTIVES AND STATUS DISPLAY (MAP)

A simplified map is shown in Figure 1. The screen displays a hierarchy on one side and topics on the other. To survey, the student may look at the introduction (either a minilesson, a sequence of digitally generated displays, or a videotape). He may also type integers or P. Typing an integer followed by the OBJ (objective) key gives a cartoon illustrating the segment objective. "P" gives the prerequisites. STATUS is indicated by coloring the boxes red, yellow or green to indicate trouble, uncertainty, or clear progress. Typing "X" gives a similar map for AB test, AB work, and games, simulations and other "fun options."



<u>E.8.5</u>

1. The Complete Verb Phrase
2. Uses of the Verb "to be"
3. Memorizing Be Verbs
4. Recognizing Have Verbs
5. Recognizing the Modals
6. Memorizing Modals
7. Identifying Verbs

Figure 1. Lesson MAP

At the course level, the boxes represent unit objectives; at the unit level, they represent lesson objectives and at the lesson level, they represent segment objectives.

To permit the student access to any level of the courseware, a learner control command keyboard was designed. It is illustrated in Figure 2. The ATTN key signals that a typed command is forthcoming (e.g., logon, logoff, calculate). BACK displays the immediately preceding screen image. SKIP permits by-passing a test item and certain other functions. NOTE records a comment for the author and EXIT pops back to a level from which the student exited for some operation. The nine keys at the bottom of Figure 2 are involved in the learner's control of his own learning tactics. The RULE, EXAMP, PRACT, EASIER, HARDER, HELP, and OBJ keys deal with events within a segment while the MAP and ADVICE keys are more general.

On a course or unit map when the student selects a box, he pushes the "GO" button and drops to the next lower map. On a lesson map, when the student selects a segment, he pushes the "RULE", "EXAMP" (example) or "PRACT" (practice) button to interact directly with the content. Following any of these three buttons, he may push EASIER, HARDER, or HELP to vary the instructional variables which he may require for effective learning.

From the lesson map illustrated in Figure 1 and from the primary instruction keys may be inferred the various content files which compose the modular courseware data structure.

The three main primary instruction learner-control buttons are related to the presentation form dimension of the taxonomy of instructional variables as indicated in Figure 3. This figure also shows how the EASIER and HARDER keys are related to inter-display relationship variables, and the HELP to mathemagenic information.

The function of the nine principal learner control command keys is as follows:

RULE — Accesses the main generality for a segment. For a concept, this is a definition, for a rule it is a clear statement, for memorization it describes what is to be memorized.

EXAMP — Accesses the next instance in a file of expository instances. The sequence of instances is constructed so that matching, pairing, and other instructional variables, not appropriate for student control, are built in.

PRACT — Accesses the same instance file as EXAMP, but presents it in inquisitory mode, with necessary answer processing for student-entered constructed responses.

Figure 2. TICCIT Keyboard

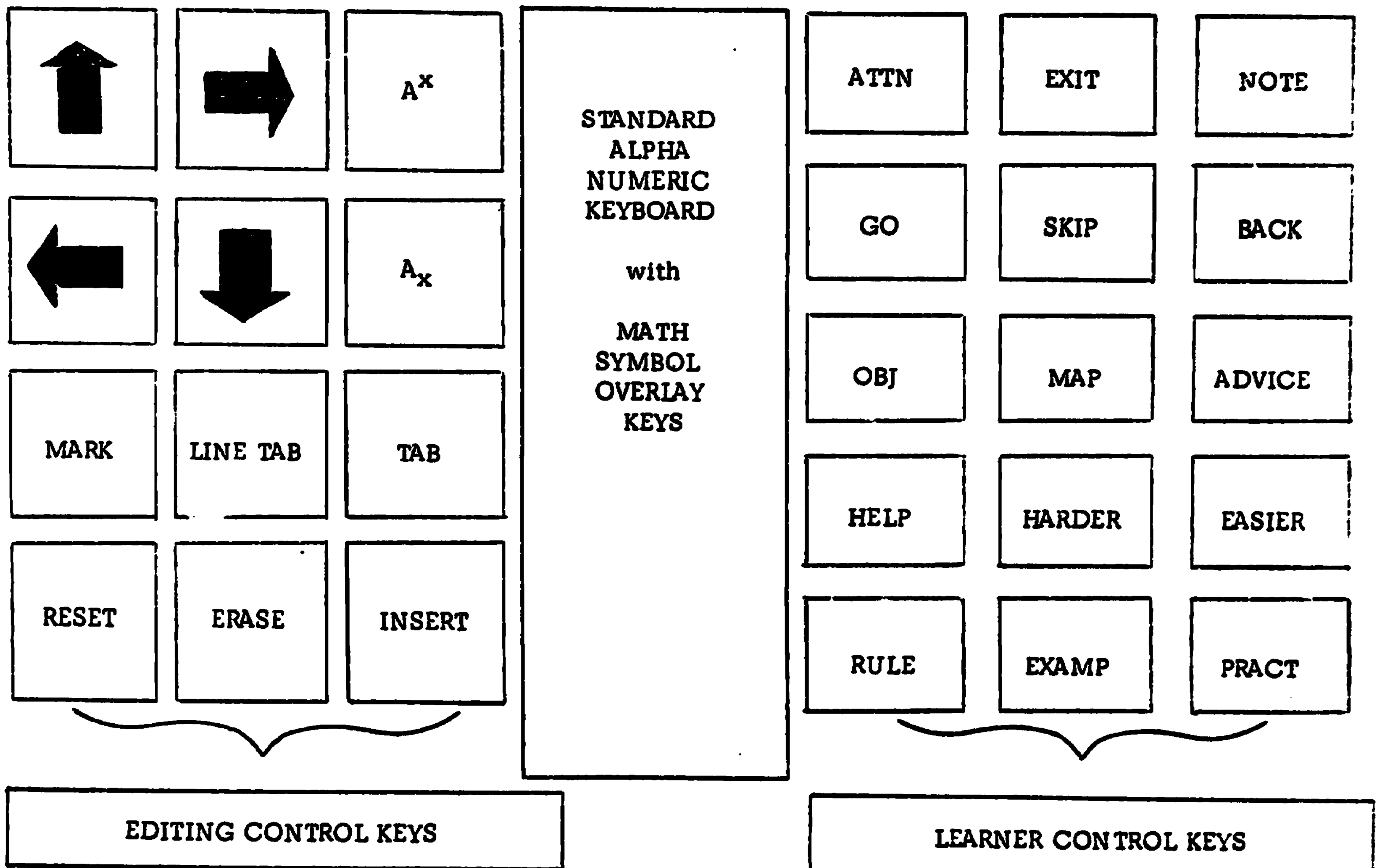
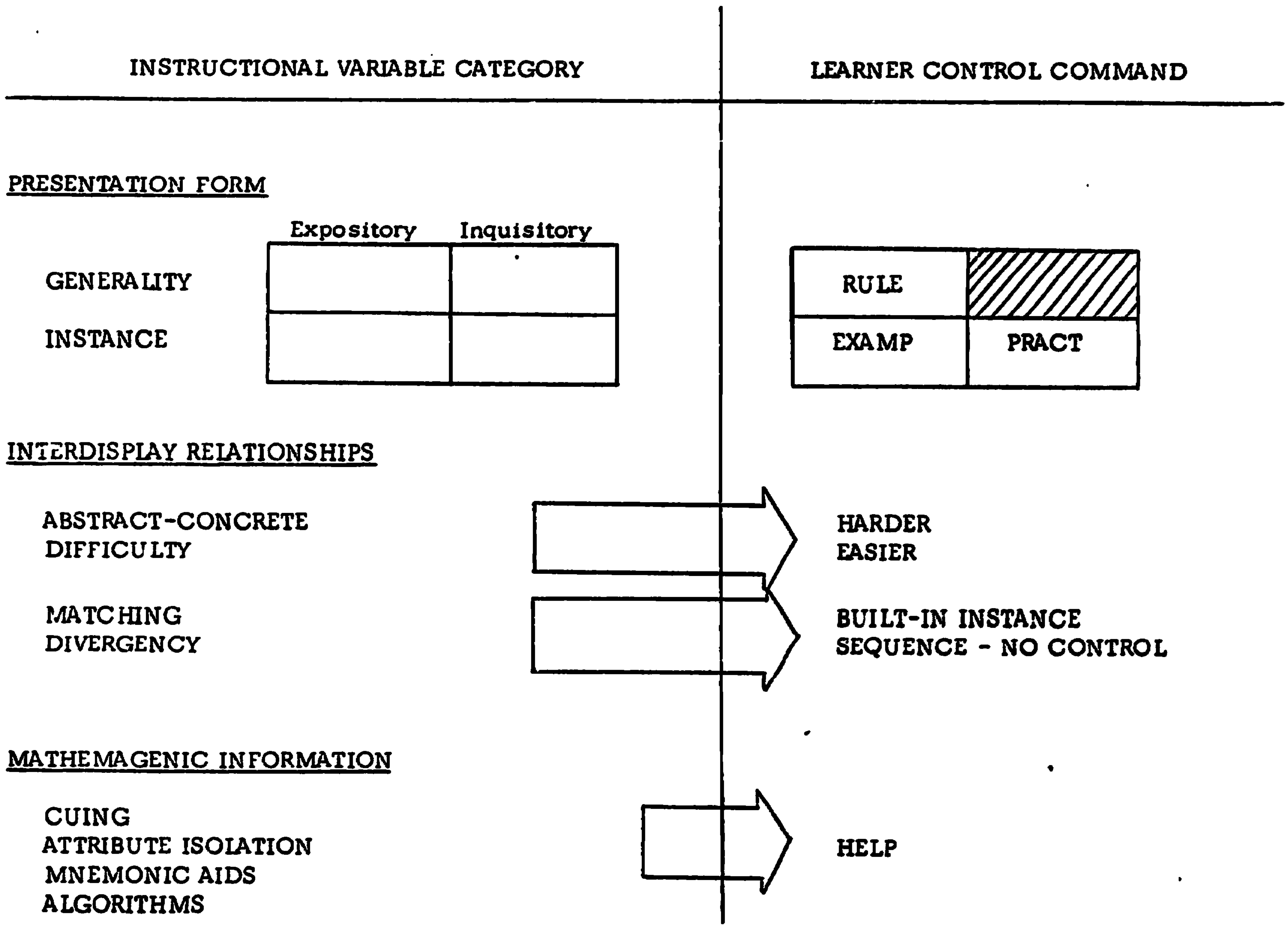


Figure 3. Relation of Learner Control Commands to Instructional Variables



RULE may be followed by:

EASIER More concrete form of rule (an analogy). Simpler terminology.

HARDER More abstract. Technical notation and terminology.

HELP Mnemonic aids to remember the rule. Attribute isolation of key terms or characteristics using color, graphics and audio. These displays may be followed by an information processing sequence for using the rule or testing instances of the concept.

PRACT or EXAMP may be followed by:

EASIER or HARDER Shifts to easier or harder instances.

HELP Instance specific attribute isolation using color, arrows, sometimes graphics and sometimes audio. Aids to recall the rule are presented first, followed by a step-by-step walk-through of a good information-processing algorithm for using the rule or testing the concept, specific to this instance.

EASIER and HARDER are typically "inter-display relationship" variables while HELP provides "mathemagenic information," although this distinction does not always hold in the case of EASIER.

Matching of examples and non-examples and a default sequence generally going from easy to hard and covering the necessary range of divergency among the instances is built into the instance files and their controlling logic. A principle in the design of learner control was that students should be given control only over those variables for which they had or could learn a basis for intelligent choice.

There are five basic kinds of content files and additional files for display formatting and answer-processing.

Map files include the objectives and prerequisites for survey, and the INTRO content for course, unit and lesson maps.

Generality files provide for each segment a main generality, an easier version, a harder version and a "help" file for the generality.

Instance files include for each segment a sequence of between about twelve and forty instances. The instances are classified as easy, medium and hard and are available in expository or inquisitory modes. For each instance, a help file specific to that instance is available. In inquisitory mode, answer-processing and feedback is available. Instance files may be defined by generative algorithms as well as by a set of discrete items.

Test files for each lesson are made up of instances similar to those found in the inquisitory instance files. AB level tests are also available. Unit and course level tests may be provided, although they are often off-line.

Fun options are games, simulations, tidbits of humorous or interesting information, and options to look at extra videotapes of interest. These are made available on the same map with the AB work, hopefully to induce students voluntarily to choose optional work.

The learner-control command language provides the student with a means to access any file with few restraints. He may be forced to listen to and look at advice if he is going astray, but he is never forced to look at any instructional material that he does not select.

From the above description of courseware content structures, it is possible to summarize the strategy for achieving the goal of mastery. Each student has an idiosyncrastic requirement for instruction on the various objectives which constitute a course. Through the map displays and through the status reports using this map display, he can select which objectives he needs and, within broad restraints set by the prerequisite relationships between lessons, the sequence of objectives. Within an objective, which typically teaches a single concept or rule, students vary on the level of abstraction, concreteness, difficulty, and the help they need to understand how to perform on the practice items which test that objective. The tactical sequences possible by various students are unlimited. The slower students will need more EASIER displays and more HELP. They will probably need a greater number of instances. Brighter students may use a discovery approach, focusing on the harder practice instances. They will have less requirement for HELP and for the alternate rule displays. Status reports signal the student when he has achieved mastery, so that all students who can read the displays are assured that if they keep working they can eventually reach a mastery state.

Efficiency.--The careful analysis of content into learning hierarchies typically increases the efficiency of systematically designed instruction in comparison to classroom instruction, since incidental material is deleted. Furthermore, students can skip those objectives which they already know. At the level of the tactical sequences of primary instruction keys within a segment, we also hope to improve efficiency by helping the student devise his own characteristic plan of attack, modifying it as needed. The advisor program and status displays constitute the design techniques used to achieve this goal. It is expected that learner-control will be less efficient, at first, than would a skillfully designed adaptive sequence based on research and controlled by the computer. The hypothesis is that given adequate status displays, a reasonably good advisor, and practice, students can develop skill in strategy and tactics which will exceed the efficiency possible through program control.

Improved Strategies.--Assume that the art and science of mathematical modeling of the learning process should evolve to the point where greater levels of mastery and efficiency could always be obtained by computer control than by learner control (a possible future which we doubt will occur). Even then, learner control would be preferre . The goal of improved strategies and its companion goals, improved attitudes of approach and responsibility, should not be subordinated to the quest for efficiency.

Previous research on learner control at the University of Texas (eg., Judd, Bunderson and Bessent, 1970) did not seek to establish relationships between the availability of learner control and the growth in strategy competence, approach and responsibility. The conception of learner control was too narrow, both in relation to the outcomes of learner control and the means to implement it. The available CAI programs were too short in duration for much skill in learner control to develop and the courseware data structures lacked the modularity and the relationship to instructional variables inherent in the TICCIT courseware design.

A broader concept of learner control requires better answers to the questions: What is to be controlled? How is it to be controlled? On what basis do we expect the student to learn to control it? The taxonomy of instructional variables described above gives a framework for answering the first question: The student should have control over instructional variables which can make a difference in his learning. The variables reviewed and classified in the paper by Merrill and Boutwell (1973) were divided into those which could readily be manipulated by the student and those which, at least for now, should remain under the control of the authors and the computer.

The results of this decision process are described above in the discussion of the MAP logic, and the primary instruction commands.

How are these variables to be controlled? Earlier learner control researchers had relinquished control to the student in a fairly ad hoc and non-systematic manner. Because of the lack of separation of strategy and content in the various tutorial CAI languages, choice of options was thrust unexpectedly into the hands of students at content specific decision points. A more rational approach developed in later years (Schneider, 1972), but these approaches were still limited in the range of variables placed under student control. The TICCIT design for learner control viewed student-machine interaction as a communication process requiring a formal command language--a language related to the variables which affect learning.

A model for student-machine communication developed by Pask (1967) provided one source of inspiration for the learner control command language implemented in TICCIT. Pask asserted that all communication between student and computer can be described as taking place in one or more special languages. The flow of instructional information sequenced according to fixed algorithms within the computer, and the answers to questions and problems entered by the student comprise what Pask calls the L^O language. Discussion about the instructional process itself, and attempts by the student to control the process in some way, take place in L^1. It is possible also to define an L^2 language in which control processes can be discussed and modified.

In the TICCIT system, we speak of progressively higher levels of discourse, analogous to Pask's languages.

Level 0 may be implemented primarily within the files of instances where students may look at worked examples or may practice. Level 1 is implemented by means of the MAP logic and the primary instruction keys. Level 2 is implemented by an advisor program, which refers to a set of student historical data (monitor) and communicates by reference to "status displays" at course, unit, lesson and segment levels. The advisor also communicates through audio and through blue-colored visual displays.

The concept of a learner control command language and advisor which permits discourse between student and machine at all three of Pask's levels is the key element in the design approach to improve student strategies. The elements missing from earlier implementations of so-called learner control were the instructional variable-related commands, the status displays and the advisor.

These latter elements provide an answer to the question: "On what basis may the student learn improved strategies?" Given instructionally relevant commands, well-defined goals (objectives and tests on MAP displays), and status reports which reveal the discrepancy between present status and desired status, students have the information necessary to initiate strategic and tactical decisions. The availability of an advisor permits the student to request suggestions on which strategic or tactical decisions might be appropriate at any time during the process of instruction. The advisor also monitors the student's choices and offers unsolicited advice about strategy on tactics when the student departs from a generally useful model.

By means of the advisor, the goal is to help the student learn to use the status displays to guide his own initiation of strategic and tactical maneuvers, until he becomes independent of any requirement for advisor support.

Figure 3 illustrates the four parts of a strategy, along with the commands from the learner control command language or from the MAP display which allow the student to control each part of his strategy.

A survey is effected primarily through the use of MAPs at the course, unit and lesson levels. Any map permits access to the introduction, videotape or minilesson, to the objectives, the prerequisites, and any rule display. The student may survey any unit and lesson in the course freely, but he may not work on instances or tests on any lesson for which he has not completed the prerequisite lessons.

Learning tactics occur within a segment, and use the primary instruction commands RULE, EXAMP, PRACT, EASIER, HARDER, and HELP in any sequence, except EASIER, HARDER, or HELP must always be preceded by RULE, EXAMP, or PRACT.

Testing tactics take place in the practice files for self-testing, and in the lesson and unit tests. Students get three attempts at the lesson-level working tests. The students with higher aspirations or with greater approach responses may also elect on certain lessons to take the XTRA work. Typing XTRA provides another MAP with fun options and more advanced concepts and rules. An "AB" level test is provided on the XTRA map for which only one attempt is permitted.

Review tactics are permitted at any time. The student uses the survey and learning tactics commands. Within a lesson, review mode is identical to initial learning with the exception that no scoring occurs and the advisor is limited to a few simple, general comments about review strategy.

Approach vs. Avoidance.--What variables effect positive affect toward learning a particular content? The taxonomy of variables on which the TICCIT courseware was built is a classification of variables which effect mastery learning, not affect. One point is clear: It is impossible even to measure approach without permitting free choice. Voluntary choice is a requisite for the measurement of an affective objective (Lee and Merrill, 1972).

The designers of TICCIT hypothesize that learner control will also contribute to the development of approach responses. The XTRA menu is one means to implement this concept. The AB level test and extra work is designed to be strictly voluntary. The extent to which students spend time on these materials is one possible way to access the growth of approach responses.

Effective instruction may be the most powerful variable in producing approach. A sense of accomplishment, and a recognition of growing skill at strategy and tactics may lead the student to choose optional work during TICCIT instruction and more significantly, elect to take more advanced math or English courses not using TICCIT, which he otherwise would not have taken.

The introductory videotapes and minilessons are designed to produce a positive attitude toward taking each TICCIT lesson. In addition, the use of color, graphics and low-key humor are designed to lighten the task of learning.

Responsibility.--Like approach, the growth of a sense of responsibility is an outcome for which the controlling variables are not well understood. The modular design of TICCIT, with its clearly defined outcomes of mastery and efficiency, provides an opportunity to observe variations in indices related to responsible use of time and resources. The extent to which appointments are scheduled and kept provides a gross measure. Day-to-day fluctuations in efficiency provide a more fine-grained measure.

The design strategy is based on the assumption that growth in responsibility occurs when responsibility is clearly fixed and help is provided to assist the individual to carry that responsibility. An over-riding tone pervades the courseware and the advisor program. It says wordlessly that the responsibility of the authors is to provide effective, interesting instructional resources, and helpful advice. The responsibility of the student is to select his own goals (at registration) to plan a sequence of subgoals and to apply himself actively to the task of achieving these goals.

The training of proctors and teachers is a key aspect in the strategy to achieve improved responsibility. An increase in the student's responsibility to control his time and his learning activities is accompanied by a decrease in the teacher's responsibility. The great lesson of parenthood must be learned by teachers: To permit the growth of your children or your students, it is necessary to let go and permit free choice. Freedom of choice means that the child or the student can choose a course that produces failure as well as a course which leads to success. If provided with sufficient information about the process that led to success or failure, the student can learn from his experience. Teachers and proctors must learn not to step in and rescue a student from an impending error, but instead maintain a problem-solving nonjudgmental attitude and provide help when requested.

In summary, the design strategy for effectiveness goals is based on a review of instructional variables effective in complex cognitive learning, particularly in concept and rule learning. Certain of these variables were put under the control of the student by means of a learner control command language. The student uses this language to survey the course, plan an overall sequence strategy, for learning objectives, developing specific learning tactics for each objective and developing his own testing and review tactics. Status displays help him focus his efforts and make strategic and tactical choices. An advisor program helps him learn the command language so that his strategies and his level of mastery and efficiency will improve simultaneously. In addition, improved attitudes of approach and responsibility are sought through global aspects of the courseware design and through the manner in which teachers and proctors are expected to interact.

ROLES FOR EDUCATORS

The roles of manager-advisor, master teacher, instructional designer-developer and instructional researcher are not new roles. Good college teachers at many campuses now demonstrate all or most of the skills discussed below in relation to the existing systems of instruction they deal with. TICCIT may cause sharper definitions and distinctions to be made in these roles and will bring to a head issues regarding the distribution of a faculty member's time across various roles. The issue of incentives, both financial and professional, for time spent in new roles will become especially crucial.

The manager-advisor role is a substantial departure from that of being the central figure in the classroom. Management by objectives, as developed by experts in fields other than education, uses similar principles. The teacher helps the student select goals and plan actions, evaluate the success of those actions, and modify plans accordingly. The student grows by assuming responsibility for his own goals and plans. The system of materials in the computer is a resource structured both to facilitate goal setting, strategy planning, learning tactics and evaluation. The teacher is a source of help rather than a dispenser of information and a judge. The teacher and proctor training courses to be developed prior to implementation in the colleges are designed to help define the new roles of manager-counselor. As noted above, this role is related to the growth of an attitude of responsibility in students.

Master Teacher.--The TICCIT implementation plan does not include explicitly the role of master teacher, for this must occur in more advanced courses which follow the basic TICCIT math and English series. Teachers confronted with the idea of computer-assisted instruction fear that certain of the imponderable values of education can never be conveyed by computers. Most of us have known an outstanding teacher who exerted a strong influence on our lives, either as a model of the kind of person or professional we would like to become, or as someone who conveyed a love for a particular subject, or a creative approach which may have enriched our life or even changed the direction of our career. Confronted with a set of objectives for the TICCIT courseware, or any systematically designed instruction with measurable objectives, experienced teachers immediately fear that something important may have been left out. When the source of this concern can be defined, it often turns out to be a matter of style or of professional judgment in a debatable area. Sometimes it is a complex behavior, like creativity or advanced problem solving, which can best be addressed in more advanced courses. Often it cannot be defined or even clearly articulated.

Computers demand the great discipline of making things explicit and operational. If certain hard-to-define values or goals are not taught by the TICCIT courses, at least now an operational definition of what these things are not will exist. Let the master teacher in the more advanced courses demonstrate in the lives of well-prepared students what these values are. TICCIT thus offers a friendly challenge to teachers: Take the hopefully well-trained graduates of the freshman math and English courses who have demonstrated explicit operational skills, and convey to them the things which the computer and the teachers in the manager-advisor role could not convey.

The proper question regarding computers in instruction is not "Can computers replace teachers," but "For what subjects and students should instruction be carried primarily by machine, when primarily by a teacher, and when as a shared responsibility between teachers and machines." By demonstrating courseware and organizational models in two subjects as diverse as high school through freshman college level mathematics and basic college level English composition, the TICCIT project seeks answers to these questions.

Instructional Designer-Developer.--It has been noted often that college instructors are not taught how to teach. Yet even the extensive research in teacher education has emphasized interaction skills, and seldom deals with design and development skills.

The invention of learner-controlled courseware was accompanied by the concurrent development of a team approach to the design and development of materials. These roles are described in greater detail elsewhere (Bunderson, 1973). Briefly, teachers may serve as subject matter experts on such teams. Other professionals receive training as instructional psychologists, who formulate strategies and who work interactively with subject matter experts in content analysis and content component design. Technical personnel serve as design technicians, evaluation technicians, graphics specialists and coders or "packagers."

One objective of this project is to provide documentation and later training, so that others can organize teams and develop courseware designed toward their own goals and values.

The availability of TICCIT computer resources for new development also offers teachers a new means to achieve some of the values not accomplished in the basic TICCIT courses. The computer can be used for modeling, simulation and the development of small packages as adjuncts to the teacher in classroom and laboratory, especially in more advanced courses. This mode of computer use has been shown to enrich greatly the educational experiences of both teachers and students. By meeting the cost goals and thus potentially catalyzing a mass market, the TICCIT project can lead to the widespread availability of low-cost computer resources for teachers and students interested in these adjunctive uses.

Instructional Researcher.--Research on human learning and instruction as it is practiced in universities can often justly be characterized as being irrelevant to real instruction. Applied research, on the other hand, may be so content specific and situation specific as to possess no generality. The design science approach to instruction, the modular courseware data structure, and the data recording facilities of TICCIT offer a middle ground. Community college teachers, freed of some classroom responsibilities, can investigate the effects of instructional variables, management variables, and social variables on any of a number of effectiveness criteria, with real hope of generality. This type of research has too much of an applied flavor to appeal to most educational researchers in universities, steeped as they are in descriptive natural science-based research paradigms and philosophies. The field is open to undergraduate instructors to make the professional contributions they would like in research. On the one hand, TICCIT provides instrumentation unparalleled at most educational research centers. On the other hand, many college instructors have research training, are getting it in connection with graduate work at nearby universities, or can obtain it.

The TICCIT project as initially conceived made provision budgetarily only for the transfer of the manager-advisor role to the faculty of the test colleges. This was to be done through the development of a teacher-proctor course to be conducted at the colleges immediately following the installation of the equipment and prior to the full-scale demonstration. As the project has evolved, much interaction with the faculties of Phoenix College and Alexandria Campus has revealed the intimate relationships among all four roles. An implementation plan has been formulated and is evolving as of the date of this paper to provide details on how all aspects of physical arrangement, organizational patterns and role definitions at each college will be handled. No faculty will lose their jobs at either college, regardless of hoped-for improvements in productivity which may make a smaller staff feasible in the TICCIT courses. Colleges can greatly benefit by turning the talents of faculty into improvements in more advanced courses (master-teacher role), new instructional development and instructional research, but they must establish the professional and economic incentives and organizational structures to make this possible.

Numerous institutional and sociological problems must be solved before state legislators, state boards, trustees, college administrators and faculty committees on tenure and professional development will permit an environment in which the diverse roles and contributions discussed above can flourish. Such social and institutional change is beyond the scope of the present project. As designers and developers, we can only convey some ideas, design the system to provide the opportunities, transfer what information we have and root for the visionary and courageous faculty members and administrators at the two colleges to find ways to accomplish rewarding and productive roles for educators.

For those who fund the colleges, the idea that an institution-specific research and development capability can pay for itself in faculty satisfaction, student growth and increased productivity will require much proof.

INSTITUTIONAL GOALS

To achieve the low-cost operation projected as a design goal, the TICCIT hardware had to be unique. As a non-profit systems engineering corporation, the MITRE Corporation was able to select from existing off-the-shelf components. They picked minicomputers and television technology to mediate the TICCIT system. The configuration consists of two NOVA 800 minicomputers, a terminal processor and a main processor. The terminal processor handles communications with 128 color TV terminals. It also provides keyboard echoing from the 128 keyboards and formats and refreshes displays (a television image must be refreshed 60 times per second). These displays may consist of any combination of characters, representing symbols from any language. Special character fonts may be created "on-the-fly" by a sophisticated display generator. This same display generator is able to create digital graphics either of the mathematical function variety or of a free-form cartoon variety. Any of these graphic displays, either character or pictorial, may be colored down to a resolution of 1/2 character in any of seven brilliant colors. This color display and the graphic capability is extremely powerful for the prompting and cuing aspects of instruction.

The television terminal may also be used as a display medium for videotapes, which may be switched from a bank of videotape players housed at the central computer. The terminal processor handles this operation. The terminal processor also retrieves the digital graphics from a magnetic disk for display on the television sets and retrieves digital audio from disks and switches it to the terminal.

The main processor accesses the large data bases of content files produced by the authors and executes the program logic. The operating system is designed around the educational requirements generated by the design goals and is more efficient for this purpose than a general purpose time-sharing system.

By using these off-the-shelf components and minimizing new development, the MITRE Corporation has been able to keep the cost of the 128 terminal TICCIT system down to a total cost which amortizes to less than 45 cents per student hour for the hardware. The cost goal of the entire TICCIT system is to provide instruction for less than $1 per student hour for hardware, software, courseware and support personnel. By contrast, a contact hour of instruction in a community college averages $3.26. This includes all components including physical plant, library and administration. These components can be reduced by increasing the number of students which a given physical plant can support; however, the main target is the $1.50 per student contact hour of this $3.26 total which represents the costs of traditional instruction.

A major factor in achieving the cost goal is how the faculty role, faculty ratio and ratio of support personnel is eventually defined. Depending on the organizational design, TICCIT can end up costing more or less than traditional instruction. Since computer costs will decrease, the major evaluation should focus on the effectiveness goals, which have received the burden of attention in this paper.

DESIGN STRATEGY FOR EFFECTIVENESS GOALS

Previous research in CAI has shown that the average student typically finishes a block of instruction in anywhere from 15 to 60 percent less time. The probable reasons for this finding include the ability of the student to skip rapidly over that which he already knows, and move at his own pace otherwise. In addition, careful instructional analysis simplifies the objectives and structure over what is usually taught in classroom instruction. The modular structure of the system, the large amount of freedom provided by learner control and the built-in attempt to improve learning strategies are those design features of TICCIT courseware which should lead to more rapid student progress.

The goal of increased enrollment is related to the attitudinal goal of approach vs. avoidance. A positive attitude toward both the TICCIT system and the subject matter conveyed by it can influence enrollment in both the TICCIT courses and those courses for which they are prerequisite.

BIBLIOGRAPHY

Bunderson, C. Victor. "Team Production of Learner-Controlled Courseware: A Progress Report." Chapter of published proceedings of the International School on Computers in Education (ISCE) based on materials presented at the School, Summer, 1972; published in International Journal on Man-Machine Systems; also, Institute for Computer Uses in Education (ICUE) Technical Report No. 1, Brigham Young University, Provo, Utah, 1973.

Judd, W., Bunderson, C. V., and Bessent, W. "An Investigation of the Effects of Learner Control in Computer-Assisted Instruction Prerequisite Mathematics (MATHS)." Technical Report No. 5, Computer-Assisted Instruction Laboratory, University of Texas at Austin, Texas, 1970.

Lee, B. N. Writing Complete Affective Objectives. Wadsworth Publishing Company Incorporated, Belmont, California, 1972.

Merrill, M. D. and R. Boutwell. "Instructional Development: Methodology and Research." Review of Research in Education. AERA, 1973. Also, Instructional Research, Development and Evaluation Department Working Paper No. 33, Brigham Young University, Provo, Utah.

Merrill, M. D. "Premises, Propositions, and Research Underlying the Design of a Learner-Controlled CAI Instructional System: A Summary for the TICCIT System." Department of Instructional Research, Development, and Evaluation Working Paper No. 44, Brigham Young University, Provo, Utah, June, 1973.

Schneider, E. W. "Course Modularization Applied: The Interface System and Its Implications for Sequence Control and Data Analysis." Presentation given at the Association for the Development of Computer-Based Instructional Systems Conference, 1972.

Simon, H. A. The Sciences of the Artificial. The M.I.T. Press, Cambridge, Massachusetts and London, England, 1969.