

# MICROCOMPUTER-BASED INDIVIDUALLY MANAGED INSTRUCTION FOR THE HANDICAPPED

The capability of modern microcomputers to display text and pictures in many formats and colors, accompanied by voice and other sound effects, offers great potential for aiding the education of handicapped children. This promise has failed to be realized because of the inordinate effort required by teachers to master the use of existing computer-based systems and the time required to author instructional material. A new attack on this problem is being made through a joint multidisciplinary effort by the Johns Hopkins Education Division and the Applied Physics Laboratory, aided by field teams from several county school systems. Under a contract from the U.S. Department of Education, a multisensory authoring system is being developed to enable teachers to produce individualized computer-based instruction applicable to a wide range of handicaps without requiring a knowledge of programming by the teacher or major new equipment outlays by the schools. This article describes the program objectives, special educational needs of learning disabled children, derivation of system requirements, and the current status of system design.

## INTRODUCTION

For the past several years, the Applied Physics Laboratory has been collaborating with The Johns Hopkins University's Division of Education in a series of joint projects relating to the application of computers to the education of handicapped children. This activity began in 1981, when APL directed The Johns Hopkins First National Search for the Applications of Personal Computing to Aid the Handicapped.\* Other cooperative projects included evaluation of instructional computer programs for profoundly handicapped, mentally retarded, and autistic children, use of "talking computers" as communication aids for mentally retarded children or prostheses for expressive aphasics, and numerous other applications in which computers offer unique teaching capabilities. These collaborative efforts have developed a strong linkage between technology and education at Johns Hopkins, in the pattern of the highly productive association between APL and the School of Medicine.

In May 1983, a grant from the APL Development Fund and dedication of effort by the Education Division initiated a new and more ambitious collaborative effort directed to conceiving, developing, and evaluating a computer-based "authoring system" for special educators. The purpose of an authoring system is to provide a teacher with means for creating educational software programs that present students with computer-displayed instruction and tests, and record and evaluate their responses. Currently, the task of developing computer instruction ("courseware") is ex-

tremely time consuming and requires extensive training in either a standard programming language or in one of several so-called authoring languages. These difficulties have thus far effectively precluded the widespread application of computers to education despite their acknowledged potential.

The objective of the Johns Hopkins collaborative APL/Division of Education approach was to attempt to make a major advance over the rudimentary authoring systems then available, both in versatility through the use of multiple presentation media, and in ease of learning and operation through the design of a truly user-friendly system. Further, the objective was to focus on the more demanding needs of special educators, which had received little attention.

Coincidentally, the U.S. Department of Education decided in the summer of 1983 that an authoring system for teachers of the handicapped was a sufficiently important goal that it allocated funds for supporting several approaches to this problem. As a result, Johns Hopkins was awarded a contract on October 1, 1983, to develop a system along the same lines that were initially projected. This program, which is scheduled for completion by April 1, 1985, has made substantial progress in its first nine months of operation, and has been deemed of sufficient general interest to warrant a description of its specific objectives, technical approach, and current status.

## SYSTEM SUMMARY

Before discussing the detailed rationale on which the program is based, the program objectives and the system concept that has evolved from them are summarized below.

\*The results of the Search are described in *Proceedings of the Johns Hopkins First National Search for Applications of Personal Computing to Aid the Handicapped*, Publication Number 392, IEEE Computer Society (1981) and in *Johns Hopkins APL Tech. Dig.* 3, 226-277 (1983).



## Program Objectives

The general objective of the program is to develop an authoring system for teachers of handicapped children for producing individualized instruction of high quality, applicable to a wide range of handicaps, without requiring programming knowledge by the teacher or major new equipment outlays by schools. This objective is quite literally a challenge to accomplish a breakthrough in computer-aided instruction as it applies to disabled children.

Separated into its components, the specific objectives may be stated as follows:

*Individualized Instruction.* Provide teachers the means to individualize the subject matter and its sequence of presentation and of reinforcement to suit an individual student's special needs. Include the capability of monitoring student responses to assist the teacher in matching materials to the learner's rate of progress.

*Wide Applicability.* Enable educators to utilize the same basic authoring system to develop instructional material for students having a wide range of handicaps.

*Acceptability by Educators.* Assist teachers to develop instructionally sound educational exercises in a fraction of the time required by existing methods. Design the authoring system so that it is highly reliable and easy to learn and use by teachers having no previous knowledge of programming.

*Acceptability by Schools.* Provide system capabilities appropriate to curriculum requirements of state and local special education agencies. Enable the software to be used with (or readily adapted to) computer resources currently available and likely to be purchased in the future by schools.

*Superior Educational Value.* Serve as a vehicle for presenting instructional material to handicapped children in ways superior in educational value to existing teaching tools. Ensure that the system utilizes the full power of the computer, rather than simply serving as a "page turner," as some computer-aided instructions have been called.

*Long Useful Life.* Be capable of adaptation and extension to take advantage of new computer and peripheral devices so as to avoid obsolescence. The explosive expansion of computers and computer-related devices makes it essential that any new system be expandable or it will become obsolete before it is installed.

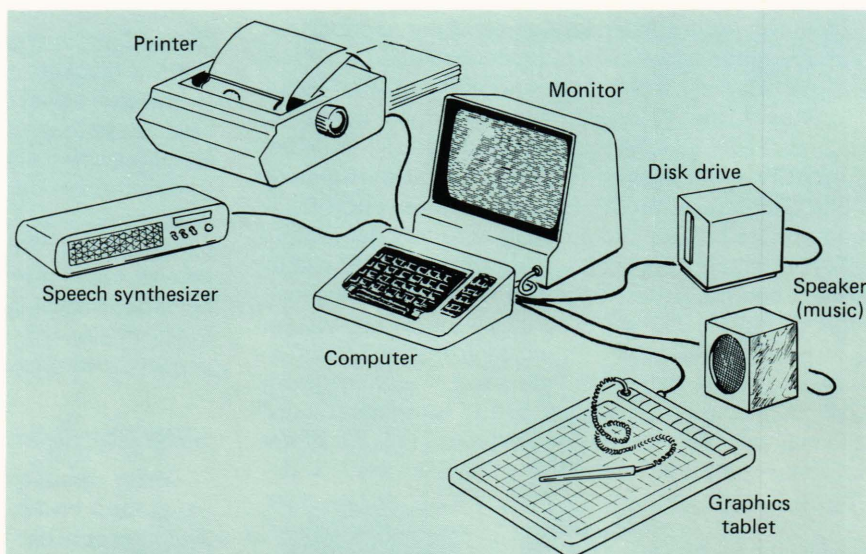
## System Configuration

The design of the authoring system can be considered to consist of a hardware configuration and a software program. The hardware portion of the system, illustrated in Fig. 1, is shown to consist of a computer and peripheral multisensory devices to enable the production of lessons using text, pictures, voice, and music to address the varying needs of students with different handicaps. The main elements are described briefly below.

*Computer.* The heart of the system is a personal computer with a keyboard and monitor, with sufficient capability to accommodate the authoring software. In order to minimize the time and cost of introducing the authoring system into the schools, the software is being sized to be accommodated on the computer most widely available in schools, the Apple II/IIe. The program consists of clearly defined structured modules. This will facilitate its transportability to other computers in the future.

*External Storage.* External storage is needed both to support the authoring software and to store and play

Figure 1—Hardware system configuration.





back the lesson. Therefore, each system will be configured to include two disk drives. For multiuser applications, a hard disk will be considered.

**Graphics.** The generation of graphics is one of the most difficult tasks of lesson authoring. The graphics tablet, with which the computer is already designed to interface, has been selected as the most immediate device that requires no programming skills on the part of the teacher. Other forms of manual graphic input (e.g., with a light pen) are becoming available and will be evaluated. Figure 2 is an example of colored freehand sketches generated using a graphics tablet. Figure 3 is a sample sketch generated using a light pen.

**Voice.** A commercial voice synthesizer and voice/sound digitizing techniques have been selected for initial evaluation and use. Provision for interfacing a voice recorder and playback will be incorporated.

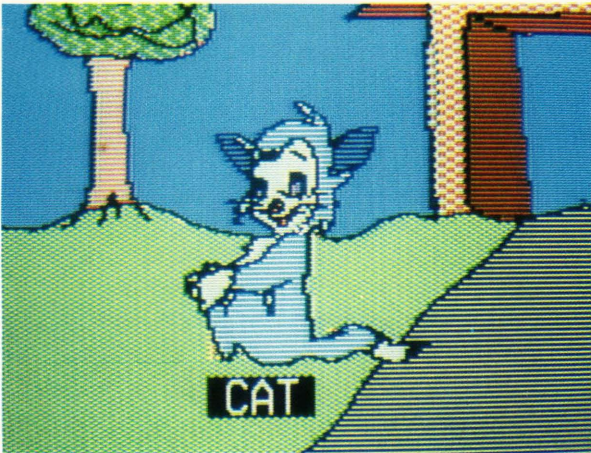


Figure 2—A colored freehand sketch using a graphics tablet.

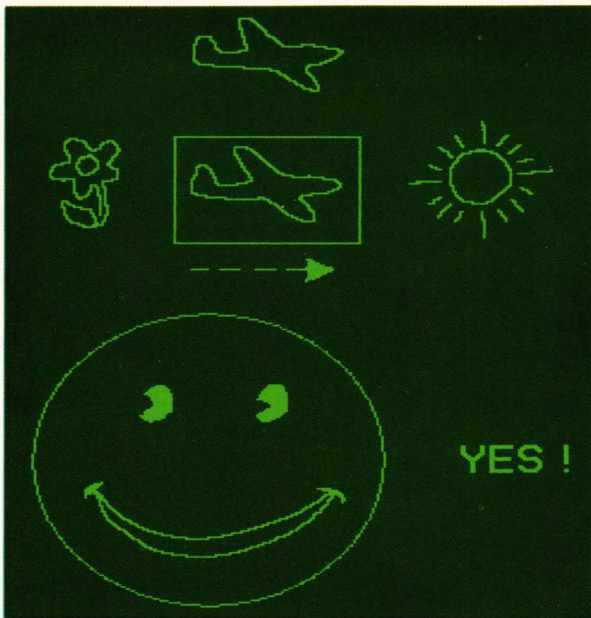


Figure 3—Sketch made using a light pen.

**Special Student Input.** The standard keyboard is not the most accessible means of input for handicapped students with physical, visual, or learning impairments, or for very young children. Therefore, in addition to keyboard entry, the use of touch screens, light pens, joysticks, mechanical switches, and levers, as well as a "mouse," will be evaluated as input devices for selected individuals. Thus, students with only minimal control over their physical movements may use the lessons available through the authoring system.

**Printers.** An inexpensive printer capable of text and graphics printouts is essential to record hard copy for the teacher, and it is important to the student because it enables him to bring home demonstrable examples of his work.

Providing for individualizable multisensory outputs in the system architecture is, in the view of educators at Johns Hopkins, critical to the success of a teacher/parent and student authoring system. Only with a variety of easily varied outputs will the teacher be able to provide the needed presentation, stimulation, and reinforcement of learning material that meet the receptive language and comprehension skills of the child, his special interests, his assets, and difficulties.

### Software Architectural Design

The characteristics of the software architecture are imposed mainly by two system requirements: (a) transportability, i.e., adaptability to run on a variety of computers with relatively minor design modifications; and (b) expandability, i.e., ability to accommodate improved or added capabilities, such as newly available interactive media, without major modifications. Both requirements lead to a design architecture that is highly modularized, i.e., made up of relatively independent functional blocks with simple interfaces, where modifications in a single block have minimal or no effect on the functioning of other blocks.

The software modular organization as it is presently conceived is diagrammed in Fig. 4. The overall organization is seen to be controlled by a System Executive, which interfaces with the computer operating system and calls all programs. In the top row are shown the five primary programs involved in the authoring and teaching/learning functions. The bottom row shows four supporting programs representing teacher assistance, analysis, and library functions, as well as possible commercial general purpose packages that would be interfaced with the authoring program. Each program is partitioned into a set of modules or packages performing clearly defined functions. The functions performed by the five primary programs are briefly stated below.

**Author Program.** Creates, organizes, tests, and edits student lessons with the support of the Text Editor, Graphics, and sound programs. By means of menus, it guides teachers to



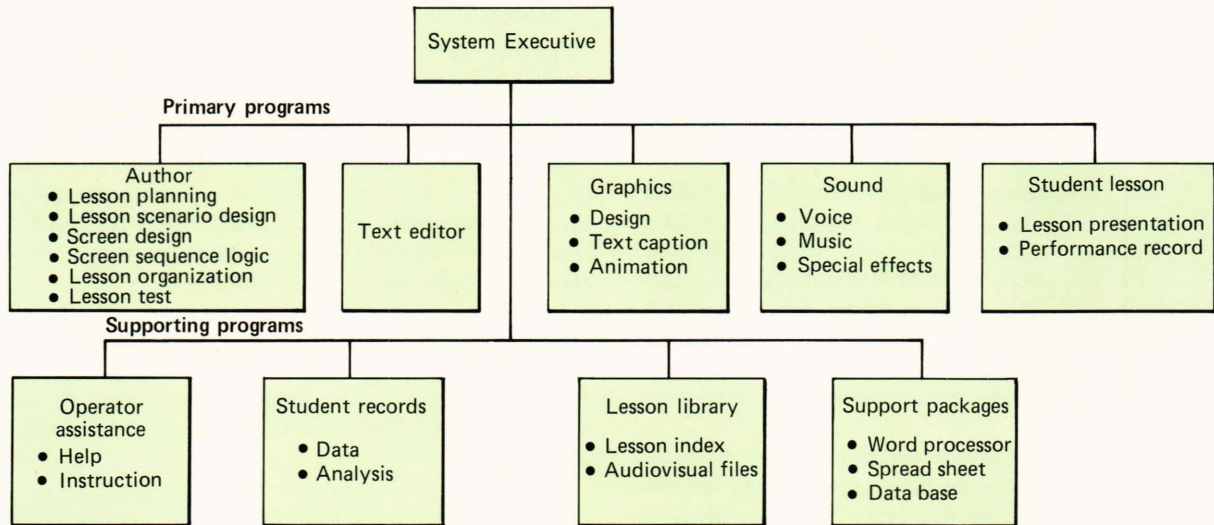


Figure 4—Block diagram of system software modules.

1. State objectives, select media, define reinforcement strategy, outline approach;
2. Define the general layout of each screen in the lesson, and define student responses to be judged correct or incorrect;
3. Translate general screen layouts into specific formats and incorporate the desired special effects with the aid of the Graphics or Sound programs or by accession material stored in Graphics and Lesson libraries;
4. Define the conditional selection of reinforcement screens as a function of the number and type of correct and incorrect responses to each question or group of questions;
5. Define the order in which the screens are to be run by the Student Lesson Program, and integrate the timing of audio and visual effects;
6. Run all or parts of the lesson for review and editing at any level.

*Text Editor Program.* Facilitates the creation and editing of a normal text entry by use of a simplified full-screen text editor.

*Graphics Program.* Enables the generation of pictures, diagrams, colors, animation, and other visual effects to augment the educational value of teaching/learning material. Guides teacher to

1. Generate desired visual images by use of “smart” graphics input devices (e.g., graphics tablet);
2. Enter special text captions on visual images;
3. Provide a limited degree of animation for enhancing the interest or meaning of visual effects.

*Sound Program.* Enables the incorporation of voice, music, and special sound effects to augment the interest and value of teaching/learning materials. Guides the teacher to:

1. Enter text in a form suitable as input to a voice generator;
2. Compose simple tunes or other musical effects as inputs to a tone generator and speaker;
3. Compose special sound effects.

*Student Lesson Program.* In the lesson mode, displays the designated screens to the student, evaluates and reacts to student responses, and creates a record of the student’s performance. This program, residing on a Lesson diskette,

1. Displays instructional, interrogatory, and reinforcement screens to the student and evaluates student responses against prescribed criteria;
2. Accumulates a record of the student’s performance on each question in the form specified by the teacher.

## PROGRAM RATIONALE

The system concept described in the previous section has evolved from a careful study of the special needs of handicapped children and the many previous attempts to apply computer technology to education. The sections that follow describe the potential of computer education in connection with specific classes of handicapped children and summarize the current status of authoring techniques. This is followed by a description of the strategic and technical approach being applied to this work, based on learning from the disappointingly small impact that previous approaches have made on effective application of computer technology to this important need.

### Potential of Computer Education for Handicapped Children

Teaching handicapped children is in many ways the most difficult and challenging problem in education.



The handicap, of whatever source, serves as a barrier that impedes the communication and comprehension necessary for learning. Even if the nature of the barrier is well understood, existing technology available to educators has not been effective in surmounting it in the great majority of cases.

As discussed in the next section, the potential of computer-based technology for aiding the educational process has been the subject of research for some 20 years, and a number of computer-aided instruction systems have been developed. Although several are in limited use at the present time, most of them have been directed to the problem of general education, with the primary objective of providing the broadest possible application for the least cost. Consequently, the objective of individualization, which is central to the teaching of handicapped children, has not been incorporated in the characteristics of technology presently available. Thus, while there is great support, enthusiasm, and anticipation for computer technology by both parents and teachers, a recent survey revealed that very few classrooms or special education resource rooms are presently using the computer as an effective instructional tool.<sup>1</sup> Evidence suggests that the primary reason for this poor showing is that those who are expert in computing generally lack the required knowledge and experience in special education, while the professionals in the field of special education have not been able to devote the time and effort required to master the special languages devised for generating courseware.

Two relatively recent advances provide new opportunities to realize the promise of computer technology in this vital area. One is the priority placed on appropriate public education for all handicapped children and youth by recent legislation and litigation, increased federal and state support, and advocacy efforts. The other is the rapidly developing technology of inexpensive but increasingly powerful microcomputers. The two together have the potential to drastically change the nature of educational practices in our schools. The very features that make computers attractive to regular teachers—their capacity to individualize the form, content, and pace of learning to fit individual students needs—are even more critical when instruction involves a handicapped student.

### General Potential of Computer Education

All handicapped students, but particularly the severely handicapped, require individualized instruction. By providing content tailored to a specific student's level and by responding differentially to the student's input, the microcomputer can become a vehicle for individualization without compromising any student's progress or requiring one-on-one teacher attention.

Closely related to the issue of individualization are the intensity and frequency of instruction. Microcomputer-based instruction has the potential to create individualized learning opportunities by teaching different content in different ways to different students.<sup>2,3</sup>

Although generating appropriate responses is an important first step, it is hardly sufficient for generating new behavioral repertoires. Relevant feedback and corrective consequences must be provided throughout the program. The sooner the teacher has information relative to the impact of the various consequences for each student, the greater the probability that the resultant instructional decisions will benefit the student. The microcomputer has the capability to process and analyze responses instantly in order to redirect the course of instruction.<sup>4</sup>

Many curriculum guides lack instructional specificity, and those that do contain this information are not necessarily followed in a consistent and coherent manner by all teachers.<sup>5</sup> Microcomputers permit detailed specification and storage of instructional stimuli, as well as of the student's responses to these stimuli. Thus, the faulty element of a presentation can be pinpointed and altered.

Microcomputers also can provide numerous trials in a consistent manner. Many handicapped students require repeated exposure to a problem before mastering a concept. Finally, the computer is nonjudgmental, predictable, and "patient." Due to these characteristics, microcomputers have produced singular successes with a variety of handicapped individuals.

### SPECIFIC APPLICATIONS

The next paragraphs review some specific applications with mentally retarded, learning-disabled, visually impaired, hearing impaired, and autistic students.

*Mental Retardation.* According to the latest figures, there were over 800,000 mentally retarded students served in the United States.<sup>6</sup> The twin philosophies that underlie instruction of these individuals are normalization and the developmental process. Domestic, vocational, functional, academic, cognition, and communication skills are the major content areas addressed. Specific skills crucial to survival in community settings, such as recognizing signs, counting change, or using public transportation, are examples of target instructional objectives.

Computer-based instruction has proved useful in teaching sight vocabulary to mildly mentally retarded children<sup>7</sup> and arithmetic and coin recognition skills to retarded students.<sup>8</sup>

In one of the few reports describing the use of computer technology to teach academic skills to preschoolers, Apple IIs were successfully integrated into a preschool class for normal children to teach the reading readiness concepts of "above," "below," "left," and "right."<sup>9</sup> The software program used color graphics, music, and voice response to keyboard inputs by the children. Not only was the readiness task successfully learned by the children, they reportedly appeared to enjoy using the computer. The children rapidly learned how to operate the computer properly and to take care of both the machine and the diskettes used to run the program.



*Learning Disabled.* A heterogeneous group of students is represented under the diagnostic label "learning disability." There are over 1.5 million identified learning-disabled students in our public schools. These students exhibit a severe discrepancy between ability and academic achievement. Therefore, the purpose of their special education programs is to bring their academic performance into line with their estimated ability levels. These students have not succeeded through traditional teaching techniques and thus are good candidates to benefit from alternative instructional approaches such as microcomputer-based instruction. Foremost among the unique advantages the computer offers in instructing learning-disabled students is the computer's potential ability to teach problem-solving skills, provide motivational drill and practice routines, and model characteristics of real situations required by the discovery method of learning.<sup>10</sup>

The multisensory capabilities of the microcomputer, in conjunction with a language experience approach, could provide a meaningful and motivational reading program for learning-disabled students. An example of such a program is an authoring system that would enable students to create their own reading scenarios and their teachers to design exercises based on the content of individual stories. Simple word processing programs would further enable the student to independently edit his work, with auditory feedback for correction and reinforcement purposes.

*Visually Impaired.* Within the population of visually handicapped persons, it has been estimated that more than 93% of these individuals are, to some degree, functionally sighted.<sup>11</sup> Thus, a majority of visually handicapped children now in school either are visual learners, or have the potential to become so.

Computers can display large-print stimuli. Furthermore, computers allow the visually handicapped individual to increase the contrast, adjust the color, and even change the graphics background from black symbols on white background to white symbols on black background. Such methods can be a decisive learning aid for a large fraction of visually impaired persons.

The ability to add voice input to computer systems is an important feature in applications with this population. Voice synthesizers that construct speech-like words, delivered in an auditory mode, are becoming increasingly more affordable and understandable.

Research has indicated that blind students become increasingly more adept at understanding synthetic speech as their exposure to this stimulus increases.<sup>12</sup> This technology allows visually handicapped individuals access to information that was previously unavailable because of their limited vision. Through the use of the computer, students can utilize standard print or braille material, edit their written work, calculate mathematical problems efficiently, and perform numerous other functions. Computers enable visually handicapped individuals to participate in the instructional environment with their sighted peers and take responsibility for much of their learning.

*Hearing Impaired.* Visual instructional media have long been recognized as effective ways to compensate for the auditory deprivation of deaf students.<sup>13</sup> However, the microcomputer and the videodisc differ from previous visual technologies in their use of random access capabilities. Thus, the microcomputer and the videodisc can make adaptive responses to an individual's response. In addition to the microcomputer's interactive characteristics, its win/lose decision-making strategies appear to be prime motivators for deaf students.<sup>14</sup>

It also appears that the student/microcomputer interaction can bypass certain characteristics of human interaction. For example, deaf teenagers, as their language deficits accumulate, often become more dependent on special intervention while they watch their hearing peers achieving progressively greater independence. The microcomputer/student interaction appears to have the potential of bypassing the sense of dependence that exceptional children feel toward their teachers.<sup>15</sup>

*Autism.* There are over 100,000 school-age autistic students.<sup>16</sup> The major learning problems that often occur among autistic individuals are physically disruptive behavior, self-stimulatory behavior, lack of motivation, stimulus over-selectivity, and the lack of ability to generalize learned skills. Some of these problems can be overcome through carefully structured teaching techniques. However, improvements in functional academic skills are virtually nonexistent for this population, comparable to the gains documented in language acquisition.

Autistic children typically do not improve as they grow older.<sup>17,18</sup> One of the reasons for this finding may be that educational programs for autistic students have not focused on functional reading, mathematics, and community-living skills. The intensity and individualization of instruction required to overcome the previously described behavioral deficits challenge even the most experienced educator.

Several functions can be built into computer software to suit the presentation to the "autistic" way of learning. In particular, a wide variety of visual and auditory stimuli can be presented via a microcomputer. In an ideal software program, the images and sounds may be changed as verification is made regarding the reinforcement qualities of the stimuli.

Another learning characteristic of autistic students is their insistence on sameness, as reflected in their resistance to change.<sup>19</sup> Microcomputers provide consistent cues and reinforcement schedules, which are unaffected by the variations typically observed in teachers' behaviors.<sup>20</sup>

Finally, the computer enables the student to be in control of the learning situation rather than a passive recipient of instruction.<sup>21</sup> Recent data<sup>22</sup> show that not only do autistic students acquire academic skills through microcomputer-based instruction, but that there are significant social gains as well.



## Current Authoring Techniques

The term "authoring system" is employed in a large number of contexts throughout the literature on computer-aided instruction. For present purposes, the term will be used to cover the processes of

1. Selecting the presentation media and format appropriate to the lesson objectives;
2. Organizing the lesson content into a form suitable for entry into the computer;
3. Entering the lesson content and editing it into the desired form;
4. Testing the computer implementation and further editing it as necessary to meet the lesson objectives;
5. Designating the data to be recorded regarding the student's performance.

Within this definition of an authoring system there has been a wide range of approaches.<sup>23</sup> The most direct has been the development of programming languages specially tailored to the needs of authoring instructional software. Prime examples of author languages are PILOT<sup>24</sup> and TUTOR, the authoring language of the PLATO system.<sup>25</sup> These languages permit a great deal of flexibility in programming but require the author to learn a special language, i.e., become a programmer. Their basic sets of keywords look deceptively simple, but the extensions used to provide the desired power of expressions end up in a full-scale programming language. For this reason, acceptance of authoring languages has been very limited.

Nonprogramming authoring systems may be classified in three categories: macro-based, form-driven, and prompting systems. The macro-based approach still requires learning a special vocabulary, although a more limited one than most author languages. Form-driven and prompting systems are truly nonprogramming approaches. In both cases, the author is assisted interactively to enter information and select alternative modes and operations, which are then translated by the software into the content and logic of the desired instructional program. Educational examples include MONIFORMS,<sup>26</sup> which was developed as an authoring aid for the PLATO system, and COURSE-MAKER<sup>27</sup> for the IBM COURSEWRITER.

## Authoring Systems for the Handicapped

The development of the great majority of author languages and authoring systems has had the aim of providing the broadest possible application of computer-based instruction for the least cost. Unfortunately, this aim is in conflict with the special priorities required for handicapped students. Whereas general instruction can be provided for the least cost through standardization, instructing the handicapped requires individualization. Since mathematics, English, and many other subjects can be taught by using textual material only, the great majority of authoring systems developed for general education deal exclusively with text. By contrast, the teaching of concepts to handi-

capped students can be made tremendously more effective through the use of combined audiovisual media, including voice, graphics, animation, music, and special effects.

The best example of the few approaches to an authoring system designed expressly for the needs of handicapped students is the product of the California School for the Deaf, Fremont.<sup>28</sup> Their first authoring system developed for a microcomputer is called BLOCKS, which prompts the teacher to compose frames consisting of a simple picture and several lines of textual material. BLOCKS is used by schools for the deaf in Canada, Scotland, and Australia, as well as in this country. (Other significant articles on general requirements and comparison of authoring languages and authoring systems are listed in Refs. 29-33.)

In summary, while a great deal of excellent work has been done in the field of computer-aided instruction, very little has been or is being directed to the special needs of handicapped children.

## Strategic Approach

From the previous sections, it is clear that the potential contribution of computers is indeed great, perhaps even greater in special than in general education. In addressing the task of developing a new computer-based authoring system for wide application in education for the handicapped, special measures have been taken to overcome the factors that have thus far thwarted the realization of this potential. Foremost among these is the establishment of an interdisciplinary team of educators thoroughly versed in the needs and special problems of handicapped children and of system engineers highly experienced in computer technology and in solving complex practical problems, working together in a pattern similar to that proved so successful in The Johns Hopkins University collaborative program in Biomedical Engineering.

In order to ensure that the product is responsive and acceptable to teachers as well as to curriculum developers and special education directors at local and state levels, explicit arrangements have been made to secure the advice and participation of individuals representing all of these activities. In addition to the participation of several teachers from local schools on the development team, arrangements have been made to field test and evaluate the preliminary and final products in a number of county school systems. An advisory board consisting of prominent educators and experts in computer applications has been established to provide authoritative advice and criticism at key periods during the process. These steps are aimed at obtaining the greatest possible feedback from the prospective users to avoid the failings of previous systems to meet practical goals.

## Technical Approach

The technical approach of the Hopkins program is directed to meet the following challenges:

1. Requirements for versatility, performance, and wide applicability usually result in large, compli-



- cated programs that are difficult to master and that tend to tax available resources.
2. The needs of students suffering from the total range of handicaps vary widely and are often difficult to relate to specific remedial instruction methods.
  3. Computer technology is evolving so rapidly that it is difficult to predict what changes are likely to occur during the development and introduction period of a new system.
  4. One of the least developed fields of interactive computer applications is the person/computer interface, which is crucial in the instructional context from the standpoint of both the teacher and the student.

The principal features that are embodied in the technical approach may be summarized as follows:

*Multisensory Capability.* To provide the quality, range, and individualization required to compensate the special disability of handicapped students, the instructional material needs to combine multisensory media. Accordingly, the system is being designed to enable teachers to present pictures, diagrams, voice, music, and sound effects, as well as to permit student interaction by a variety of input devices where appropriate.

*System Engineering.* In order to make the system adaptable to a wide variety of student needs, teaching methods, and available computers, as well as to expanding technology, a total system engineering approach is necessary. The issues involved in establishing software requirements and design approaches require a balancing of conflicting but incommensurate factors. Solutions, therefore, must derive from a true system engineering approach in which the issues are resolved on the basis of *total* system requirements.

*Available Low-Cost Hardware.* To meet the objective of acceptability by schools, the system from the outset is being designed to use or be adaptable to the computers most available in schools. The peripherals required to implement the multisensory capability are selected from those that are compatible with the above and relatively inexpensive to procure. Standardization of audiovisual effects is maximized by off-loading those functions to smart peripheral devices through standard interfaces and using standardized formats whenever possible. The design concept permits configuration of the system to use such peripherals as may be available at a given time, and to expand it as funds permit.

*“Friendly” Software.* One of the most challenging technical/human problems is that of designing an interactive software system that can be learned quickly and used effectively by persons inexperienced with computers. So-called “friendly” software is much talked about but seldom achieved. This is due not only

to the inherent conflict between versatility and simplicity, but also to the fact that the end user is seldom brought in during the critical early concept and design phases. It is believed to be absolutely essential that this particular software be truly “friendly,” and this aspect of the problem is being given highest priority.

## REQUIREMENTS AND SYSTEM DEVELOPMENT PLAN

### Authoring System Requirements

In accordance with the best practice in system development, the Hopkins program has been based on a well defined set of requirements. These were derived from a detailed analysis of the educational needs of handicapped students as well as an examination of the current approaches to the design of authoring systems.

*Educational Requirements.* The requirements that are believed to be of primary importance in providing special education with the means of formulating and adapting individualized instructions are illustrated in Table 1. Each requirement is accompanied by a brief rationale based on educational theory and research. These requirements are seen to be qualitative and will be quantified in the early stages of development.

*Requirements for Teacher Acceptance.* The limited usage of prior authoring systems has been due less to their lack of capability than to the difficulty of learning how to use them. For this reason, vitally important system requirements are those for making the system usable by teachers without prior programming skills. This not only requires the use of simple English prompts, but also a number of measures to render the system “friendly.” Some of these are listed in Table 2.

To these should be added requirements aimed at making the system compatible with school systems’ computer resources. These concern the characteristics of transportability, i.e., capability of ready adaptation to computers appropriate to the special education environment, and particularly to the majority of those presently in place.

*System Hardware Characteristics.* The general authoring system requirements impose the need for certain hardware devices for their implementation. A baseline set of hardware requirements is listed in Table 3, along with the rationale for their selection. The definition of the hardware components of the system is necessary before the software requirements can be established. As the system develops, necessary adjustments will be made in the hardware to accommodate extension of limitations that will prove necessary.

### System Development Plan

The problems to be overcome in developing a successful authoring system—one that meets the varied educational requirements, is simple to learn and use,



**Table 1**—Educational requirements for authoring system

<i>Requirement</i>	<i>Rationale</i>
Ability to vary content of program	Content must be selected on prior history and performance levels of each individual. <sup>34</sup> Must be adapted to individual learning characteristics and sensory capabilities.
Ability to present instructional stimuli through different sensory modalities	Comprehension increases when the lesson is presented through different sensory inputs. <sup>35</sup>
Ability to use branching where the student demonstrates need for further concept development	Individual error patterns vary widely. <sup>36</sup>
Ability to vary the student response mode	Must be compatible with the student's motor abilities and preferences. <sup>37</sup>
Ability to reinforce correct responses on the appropriate schedule of reinforcement	Continuous reinforcement for acquisition, and intermittent schedules for maintenance. <sup>38</sup>
Ability to provide designated contingencies following incorrect responses	Supplementary or corrective information is often required to effect learning from incorrect response. <sup>39</sup>
Ability to "call up" a student's performance	Data-based instruction has yielded consistent gains for handicapped students. <sup>40</sup>
Ability to analyze and change cues, reinforcement, and correction procedures if the student is not learning	Valuable time is lost if the student results fail to direct the course of instruction. <sup>40</sup>
Ability to empirically determine type of reinforcer for each student	Reinforcers are by definition determined by a student's response to them. <sup>41</sup>

**Table 2**—Requirements for teacher acceptance

<i>Requirement</i>	<i>Rationale</i>
Guides for the author throughout the entry process	Learning special language should not be required.
Provision of help on request	Uncertainty of what to do next is a major user frustration.
Selectable level of assistance	Experienced teachers should be able to stop unneeded steps.
Built-in protection against mistakes	Errors in operator entry should not destroy previously entered data.
Escape from system "hang-ups" without abort	Current systems usually force power turnoff to escape from hang-ups.
Manual needed only rarely	Need for frequent consultation of manual is unacceptable.
Self-learn tutorial with illustrated examples	Examples of all necessary operations are required for understanding.

and that can utilize computers already in most schools—seem to be both numerous and formidable. In order to make the best use of the available talents and funds, a detailed plan has been laid out to define an orderly and stepwise development program. The plan has been broken down into five main tasks whose products correspond to contractually defined program milestones. These tasks, corresponding development phases, and products are listed in Table 4.

### System Development Flow Diagram

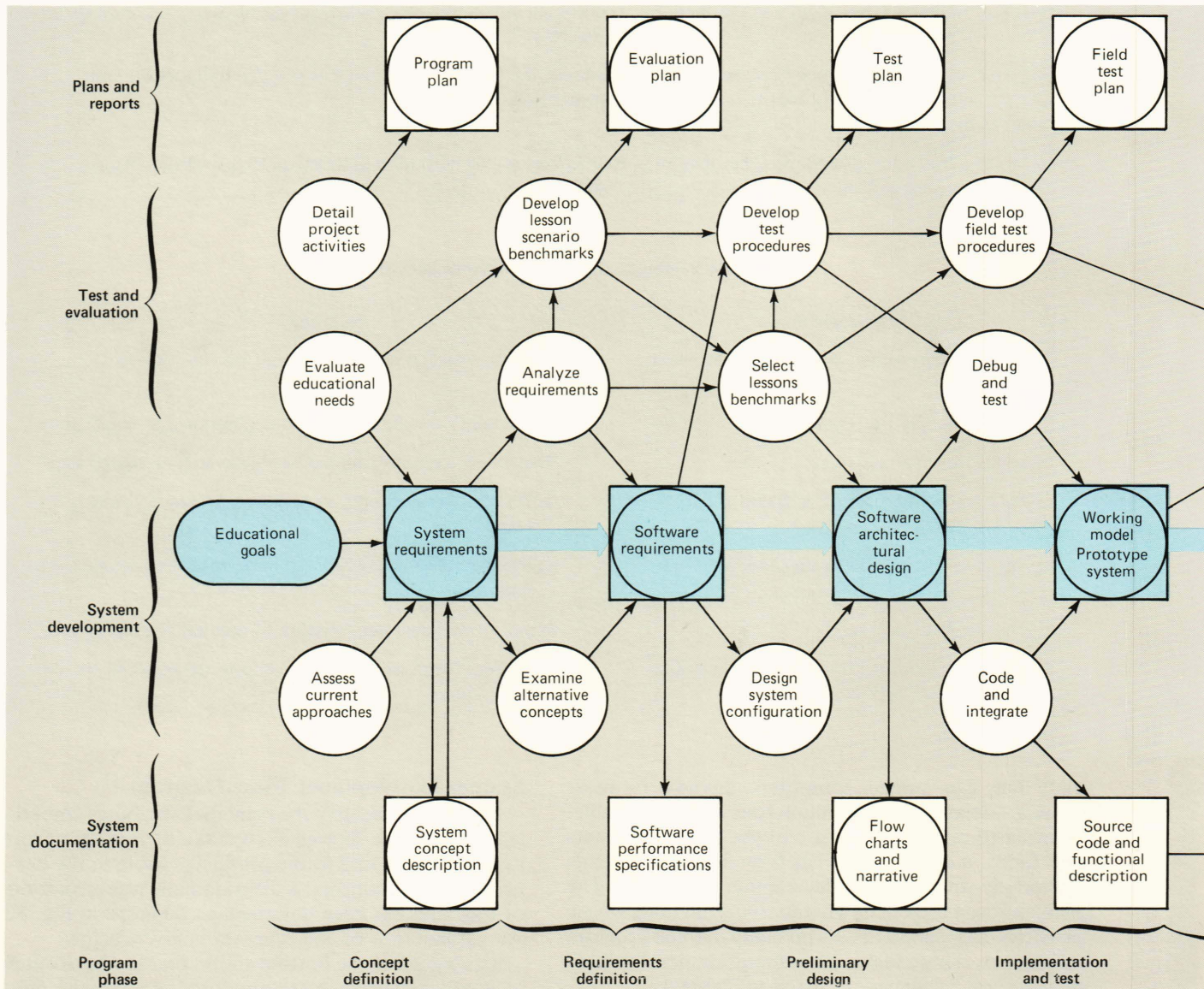
In order to identify the principal attributes embodied in each task, as well as to make their relationship to one another and to the products visible to the participants and sponsors, a diagrammatic representation of this plan has been designed, as depicted in Fig. 5. An explanation of the diagram is given below.

The legend at the bottom shows that the horizontal scale of the diagram corresponds to the successive pro-



Table 3—Hardware requirements

Requirement	Rationale
Personal computer of moderate capacity (e.g., Apple II)	Adequate for program, yet affordable by school
Color monitor	Use of color provides an important display dimension
Graphic creator/display capability (e.g., sketch pad)	Pictures essential to conveying concept understanding
Voice synthesis (and/or reproduction)	Multimedia learning; use in reinforcement
Music synthesis	Use in highlighting stimuli or for reinforcement purposes
Manual cursor control (e.g., joystick)	Essential student response mode
Direct access extended memory (e.g., disk drives)	Adequate storage and speed of response
Hard copy reproduction (e.g., printer)	Student records and student take-home displays
Provision for special input devices when needed	Adaptation to student physical handicap



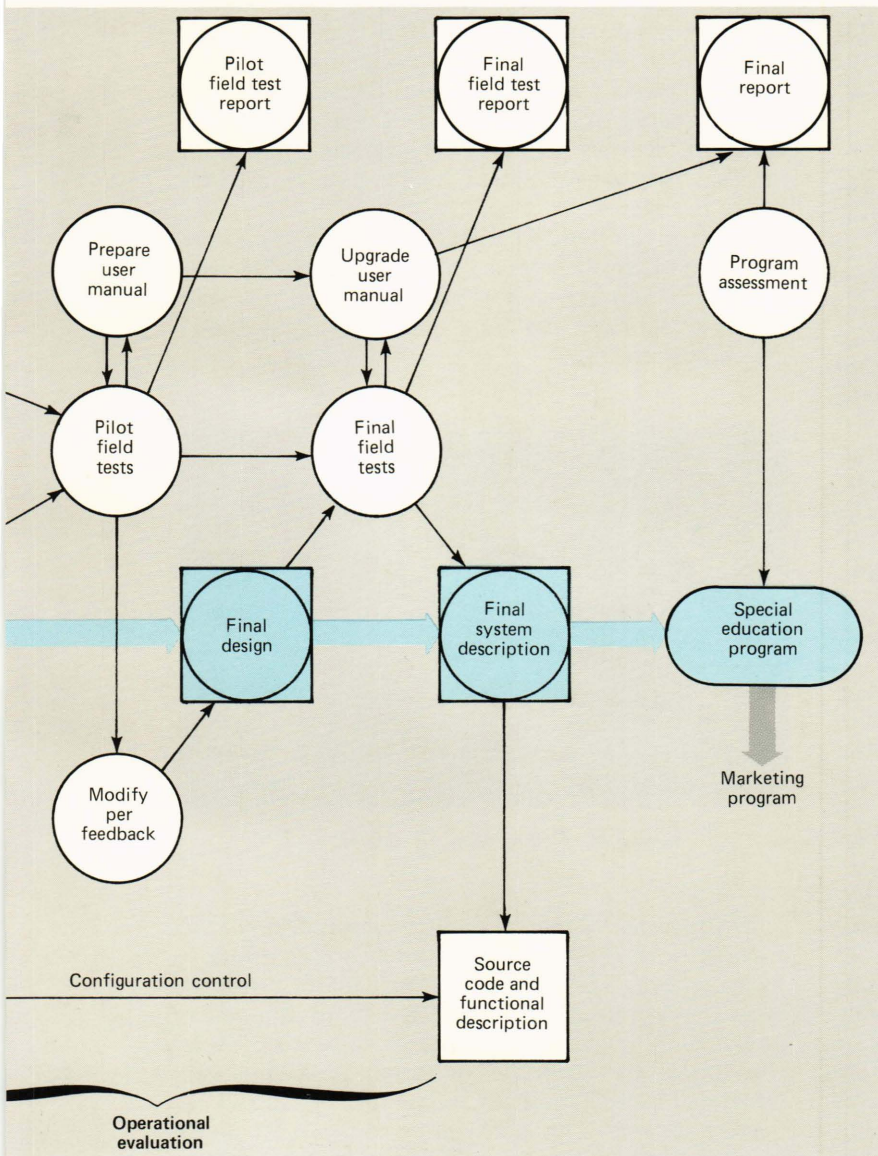


**Table 4**—Program tasks, phases and products

Task	Requirement	Rationale
1	Concept definition	System requirements System concept
2	Requirements definition	Software requirements Performance specifications
3	Preliminary design	Software architecture Software design specifications
4	Detailed design Code and unit test Integration and test	Tested software modules System prototype
5	Operational test	Final system design

gram phases. The diagram itself is made up of activities, represented as circles, and products, represented as squares. (A circle inside a square denotes the activity creating the named product.) The rows generally correspond to a given type of activity or product. Those at the top level correspond to plans and reports, which constitute the main deliverable products of the tasks. The second and third rows are activities primarily related to test and evaluation.

The main flow of development is represented by the fourth row of activities and products. It begins with the input of general educational goals as recognized by the special education community. It then proceeds through the normal phases of software system development from defining the system requirements to field testing and incorporating the results into the final product. The row of circles immediately below represents the corresponding design and development activities. The lowest row of squares are system descriptions called out as deliverables.



**Figure 5**—System development and implementation plan, phases, activities, and products.



## SYSTEM PRELIMINARY DESIGN

At the time of this writing, the development program is about halfway through its 18-month schedule. This period has been devoted mainly to three parallel activities:

1. A “top-down” definition and preliminary design of the overall system, including the definition of lesson methodologies and design approaches;
2. Development of lesson scenarios to serve as specific examples of the type of lessons the system will be designed to author;
3. Evaluation of specific multisensory devices, experimenting with graphic display modes, and developing utility programs.

All the above activities have been pursued by engineer-educator teams; weekly meetings have been held with all participants to report progress and resolve problems to ensure a coordinated approach. We believe that the multidisciplinary talents represented by the group of special education curriculum specialists, scientists-engineers, and field teams from several county school systems collaborating in this endeavor are unparalleled, and will be key to the success of this endeavor.

### Authoring Approach Organization

From the outset, the authoring system has been designed to address the entire spectrum of educational needs, rather than to focus on one or a few specific learning areas or teaching approaches. This spectrum comprises coverage of learning categories such as language, mathematics, and science, learning abilities ranging from very elementary preschool to high school levels, and utilization of visual and audio media as well as text.

Past approaches have addressed this problem either by developing a general-purpose authoring language, which has placed nearly the entire burden of lesson development on the teacher, or by providing several special-purpose software packages for individual learning categories and levels, thus providing little opportunity for the teacher to individualize the lessons or adapt them to the different learning disabilities.

The system approach adopted in this program has been to create an integrated family of authoring packages, each addressing a major class of lesson while sharing uniform authoring procedures and formats, a common set of utilities, and library facilities, all operated by a master executive. At the present time, seven principal lesson classes have been defined to cover the entire range of learning categories and levels that appear to lend themselves best to computer-aided instruction. We expect that significant learning will occur during the detailed design and evaluation period, which will result in some restructuring of the presently defined classes, and perhaps the addition of one or two more classes. Such flexibility is being provided for.

In defining these classes, it was found that lesson media and formats are more affected by the teaching methodology than by the learning skill area or sub-

ject matter. Accordingly, the classification was made in terms of teaching methodologies. The seven classes currently defined are listed below and discussed individually in the paragraphs to follow.

1. Discrimination/Matching
2. Measurement
3. Language Experience
4. Organization/Classification
5. Text Reading and Analysis
6. Functional Writing
7. Numerical Problems

*Discrimination/Matching.* An application of a matching approach to word picture association is illustrated in Fig. 6. A word, called a “target,” is displayed above a set of pictures, one of which is directly related, or a “match,” to the target word. The non-matching members of the picture set are called “distractors.” In this example, designed for students with low-level learning skills, the match selection is made by the student stopping a scanning box that successively frames each candidate picture. Successful performance of each trial is reinforced by a selected message, picture, or sound effect. During the entire lesson, a series of target words is displayed, with the matching picture and distractors appearing in random positions so that the match cannot be identified by where it appears.

The class of Discrimination/Matching is applicable to a great many different learning skills, including visual discrimination, relational association, and a wide variety of subject areas that can be handled by multiple choice selection.

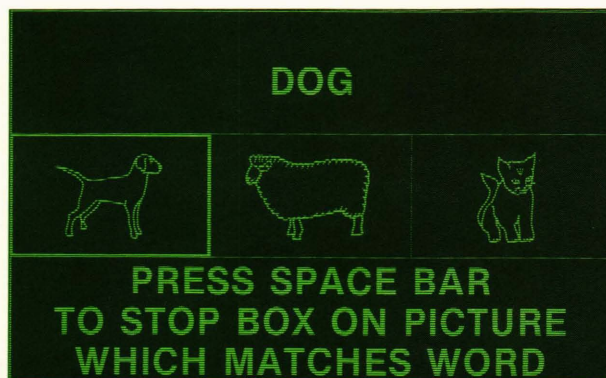


Figure 6—Picture-to-word matching.

*Measurement.* Figure 7 shows an application of the Measurement class of lesson to the learning of linear measurement. The figure is self-explanatory with respect to the graphic and text entries. In this typical example, the length of the toothbrush can be varied from trial to trial by the teacher or automatically in a systematic or random manner, as can the correct and incorrect answers. The units can be whole or fractions of an inch or centimeter, as selected by the teacher.



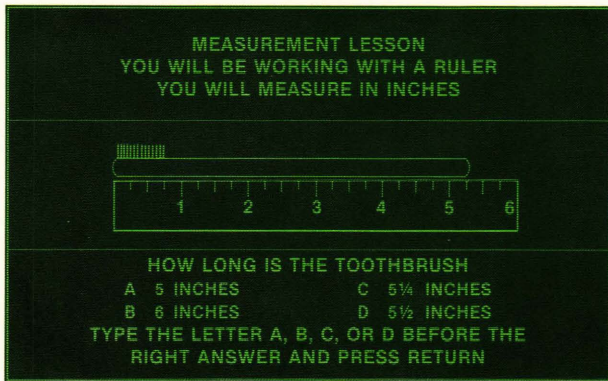


Figure 7—Length measurement.

After an incorrect answer, a line or box of the selected length can be superimposed on the picture to highlight the discrepancy.

The general class of Measurement is envisioned to include circular and area measurement; time; reading such instruments as a thermometer, speedometer, dials, and scales; and interpreting graphs. Student response may be by multiple choice or direct number entry, depending on skill level.

*Language Experience.* A primary application of this class of lesson, namely to teach the student to express himself creatively in writing and to learn to read familiar materials, is illustrated in Fig. 8. In this instance, again directed to low skill levels, the student is presented with three related pictures and asked to write a few words about each picture that relate to a connected story. For students at an even lower level, parts of the story may be provided and the student asked to fill in the blanks. In other examples, he may be presented with a single picture related to a day at the beach or some other familiar subject. This technique may also be used to help older illiterates increase their reading and writing skills.

A key element of this class of lesson is to provide the student with a simple way to correct mistakes or add to his story. In this way, the computer can help students whose manual writing skills may be an obstacle to self-expression to prepare a neat and attractive product that he can then print and take home.

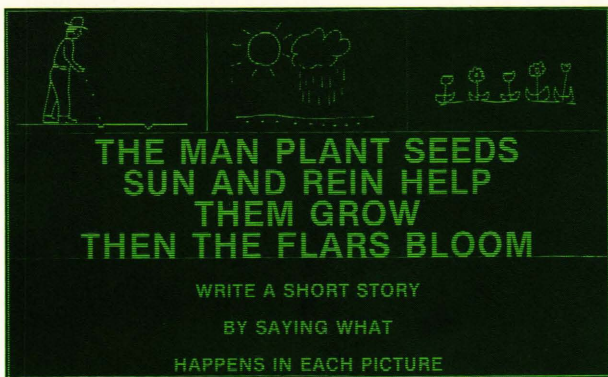


Figure 8—Language experience.

*Organization/Classification.* Figure 9 illustrates an application of this class of lesson, the organization of a list of items in terms of functionally related groups. The words at the top are seen to be names of birds, animals and fish, listed at random. The instructions at the bottom ask the student to group them in a sensible way and give the student directions for doing so. The instructions also provide for changing the groupings in case of error. At a lower level of skill, an initial assignment of one name to each group might be made. At a higher level, the number of groups might be left unspecified.

This type of lesson has a multitude of applications and can extend to groupings of much finer distinction. It lends itself to classification of pictures as well as words. As in the case of Discrimination/Matching lessons, the computer makes it possible to accomplish randomization and repetitive presentation automatically, thus taking the drudgery out of lesson design.

*Text Reading and Analysis.* The use of the computer in testing and teaching reading skills has occupied the attention of the designers and packagers of many commercial programs. Most have proved to be limited in terms of fixed context or skill level.

The Hopkins engineer/educator team has specified goals that allow teachers considerable latitude in tailoring reading/learning materials to any curricular area, varied student ability, and teacher selection of feedback and rewards. As currently envisioned, the presentation of text could be used to test immediate student recall of information, develop critical thinking skills and vocabulary, find word endings and rules for syllabication and phonic analysis, and teach grammar and punctuation.

Questions in either a direct answer or multiple choice format would appear at the bottom of a text screen (with the text removed in exercises of recall). In comprehension lessons the student would be rewarded for correct answers or guided progressively to the correct answer(s) through text highlighting.

*Functional Writing.* This general class can be applied to teaching spelling, punctuation, syllabication, grammar, story and article writing, and other skills of

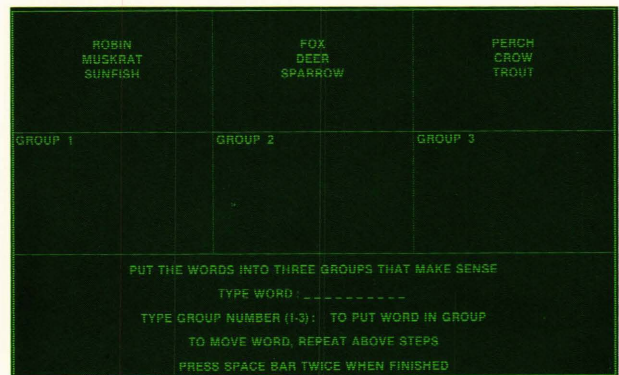


Figure 9—Word grouping.



written expression. It can also be used effectively to teach such elementary skills as how to address a letter, write a check, fill out deposit forms and applications, and other skills essential to normal functioning.

*Numerical Problems.* Whereas considerable work has been done to define the authoring requirements for handling mathematics instruction, specific formats for the more conventional methods of teaching math skills are still being analyzed. The existence of numerous conventional math instruction packages has led to the decision to place priority on applications more dependent on multisensory presentation. These include elementary concepts of mathematics, such as "picture math," that can be taught in conjunction with the matching and measurement methodologies.

### Lesson Scenarios

From the beginning of this program, system design efforts were focused on practical applications that could serve as prototype examples for evaluation by educators in the field and, thus, provide early feedback to the designers. The principal vehicle for this purpose has been defined as a group of specific lesson scenarios, each representative of one of the seven broad classes of teaching methodologies just discussed. These lessons are serving as the basis of the system design; during the formative evaluation stage, they will be used as benchmarks for assessing system performance. During the initial field test phase, the lesson plans will serve as demonstration, training, and evaluation vehicles. Ultimately, several of them will be incorporated into training manuals to illustrate the use of the system. The manner in which these lesson scenario benchmarks relate to the other elements of the system development process can be seen by referring back to the process flow diagram in Fig. 5.

In keeping with the central role of the lesson benchmarks in the development process, their design has been given high priority during the initial phases of the program. Under the leadership of educator members of the project team, a lesson scenario has now been defined for five of the seven lesson classes. The screen designs illustrated in the preceding figures were drawn from these prototype lesson plans.

### Spreadsheet Approach to Screen Design

As discussed previously, one of the chief deterrents to the use of computers in education is the inordinate amount of time that even teachers experienced in using computers have to spend to develop a new lesson. In the field of special education, the requirements for individualization and for extensive repetition of similar but nonidentical material for students with severely limited learning ability further magnify this difficulty. Accordingly, a primary objective of the authoring system design has been to find means for radically reducing lesson design time.

The approach selected rests on a key decision, namely, the definition of a finite set of patterns to be used by authors in configuring the contents of screen dis-

plays. Under the leadership of the special educators, such a set of screen formats has been defined for each lesson class, designed to accommodate the expected scope of the subject matter and learning level. A balance is struck in each case between desired flexibility and reasonable standardization. Provision is made for modifying and adding patterns during the development and evaluation stages. This approach contrasts with the free-form screen design permitted by most authoring systems.

Two major benefits derive from the standardization of screen formats. The first is, of course, that lessons developed by different teachers for the same learning application will be more alike, and hence more acceptable as a starting point for a new lesson. Thus, transferability and reusability are enhanced.

The second benefit is that standard screen display patterns inherently consist of a set of defined fields whose contents can be deleted, inserted, relocated, and otherwise manipulated in a controlled manner by computer commands. For example, in the Matching lessons illustrated in Fig. 6, the word and graphic entries do not have to be typed or drawn in exactly the proper position on the screen by the author; a word assigned to a given field can be automatically printed or can appear graphically in the specified type size and centered in that field. More importantly, the randomization of words and graphics can be done entirely automatically. Thus, once the author has entered a list of matches and distractors for each target picture and has specified random ordering, the individual screens can be composed automatically by implementing a suitable algorithm.

In applying the above concept to the design of matching and similar lessons, the screen format is treated as a set of fields whose content, once specified in terms of type and size, can be initially represented by text entries using the normal character set. When displayed, the program will automatically locate the graphic images and text in the designated fields. Figure 10 illustrates a formative screen design configured to display a series of word-picture match screens representing the reverse of the matching example shown in Fig. 6. The fields are labeled to correspond to a list of target pictures and their matching words and distractors to be selected by the author. Fig. 11 shows the screen as it will be displayed to the student. An important advantage (as referenced to existing or new pictures in the graphics library) of this approach is that using normal text in place of graphics permits the planning and formative part of lesson design and the editing process to run much more rapidly, using much less computer memory, than if the graphic images themselves, rather than text, were manipulated.

The above concept of matrix-like field-oriented screen patterns is a key feature of the very successful VisiCalc and similar software packages that present the operator with a standard electronic "spreadsheet" consisting of an array of rows and columns into which he can enter text, numbers, or algebraic expressions. These may then be manipulated by a variety of editori-



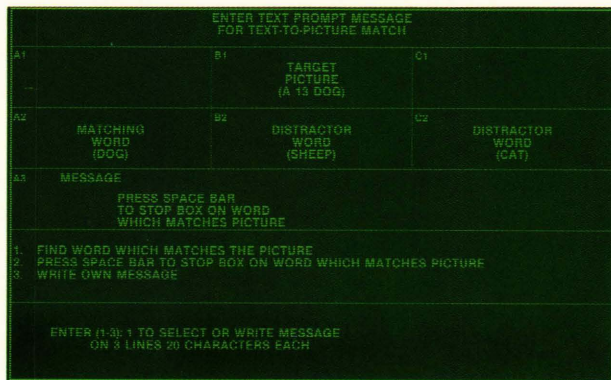


Figure 10—Authoring of word/picture match screen.

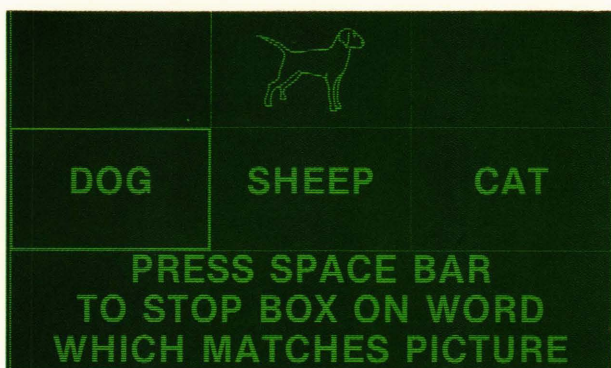


Figure 11—Word/picture matching.

al or computational commands. Whereas the computational facility is not generally applicable to lesson design, the pictorial representation and the ease of manipulation are extremely useful.

An inherent result of using textual entries to define the contents of fields to be displayed as graphic images or enlarged text is the ability to “compress” the contents of the textual screen, while preserving its relative arrangement, so as to permit the contents of two or more screens to be viewed simultaneously by the author. This is particularly desirable in composing the “reinforcement” screen design in relation to the original presentation, or during the process of editing a screen while keeping the original design as a reference.

To ensure that the textual composition of the screen contents will define a screen having the desired appearance when displayed, the system will have an “instant compile” feature, providing the author with the capability of calling up the full graphic display at any time during lesson design.

Another strategy used in the Hopkins approach to make the system easy to learn by beginning teachers, as well as powerful enough to permit experienced teachers to exploit the full potential of the computer, is an optional “fast track” with many default variables automatically entered in the system. This will allow the teacher to get on board and achieve initial results quickly. The authoring system also provides optional access to more detailed menu-driven authoring

modes that permit a much greater degree of variability and flexibility.

### Exploratory System Investigations

In parallel with the development of the education program inputs in the form of lesson scenario benchmarks and the definition of the software program structures and their basic elements, significant effort has been directed to the exploration and selection of specific hardware and software, especially those related to graphics and sound. Some examples are briefly summarized below.

**Graphics Generation.** Significant strides have been made in recent years in developing easy to use and inexpensive means for generating graphic images, and it is safe to predict that the trend will continue. Of particular interest are self-contained graphics generation packages that can connect directly into a standard interface port of a microcomputer. In addition to the game paddles, these include graphics tablets that can magnify or reduce images, light pens that can “write” on the screen, and optical image generators that convert a picture or diagram directly into a screen image. A number of these have been evaluated for use with the prototype version of the authoring system, and several are considered adequate for demonstrating most of the educational features of visual displays. In the meantime, the system is being designed to make it readily adaptable to more capable graphic devices as they become available.

**Sound Generation.** Voice communication is especially important for children who either have not yet learned to read or who are visually impaired. On the basis of an evaluation of the full spectrum of presently available devices within a reasonable cost range, it appears that, despite a great deal of effort, synthetic voice generators still lack the quality of speech that is likely to be clearly understandable by children with learning disabilities. However, they may have utility for more mature vision-impaired students.

The most promising types of devices for the application at hand are those that have a prerecorded vocabulary of words or phrases that can be assembled into understandable sentences. In using this type of device, a limitation that has to be accepted is that digitized rapid access memory media, such as diskettes, cannot store more than a relatively small number of phrases because voice recording requires a large amount of storage. Initially, therefore, it is planned to devise a natural speech vocabulary limited to essential directions and reinforcements appropriate to student interaction.

By way of augmenting this capability, the use of cassette recordings made by the teacher is being studied. This type of speech may prove useful to give extended instructions at the beginning of a lesson or at other points where a preprogrammed sequence can be used.

The amount of work going into speech synthesis, and the rapid expansion of memory, may well produce dramatic improvements in the next several years.



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