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ABSTRACT

Results are presented of a project that developed 12 social studies (specifically, directionality and geography) and critical thinking computerized instructional modules using multimedia instruction for students with learning disabilities at the upper elementary and lower intermediate school levels. Seven overarching principles were identified as critical to the successful integration of multimedia in the school curricula: establish learning objectives (knowledge); define learning process to be addressed (skills); apply skills in meaningful contextual situations; insure that multimedia provides true 'value added'; provide flexible lesson design tool; capitalize on broad spectrum of multimedia source material; and insure ease of use. The modules provide instruction in 22 thinking skills areas, with emphasis on metacognition and the cross-curricular application of thinking skills. Two additional modules were developed to assist students with mild to moderate disabilities in developing cognitive and organizational skills required for planning and shopping for meals. Information is presented on the lessons, including learning objectives and ways students can use the computer in their studies. Illustrations from the modules are included. Responsibilities undertaken by the project teams are identified, and a list is included of system features and software requirements for use in multimedia educational programs. The evaluation process which resulted in selection of digital video and optical storage for this project is outlined, and use of a multimedia rapid prototyping tool to allow team members to visualize and dynamically run a model of proposed software is described. (SW)

ED 385 111

TECHNOLOGY: EDUCATIONAL MEDIA AND MATERIALS FOR THE HANDICAPPED PROGRAM

Grant No. H180C00007-91

Final Report

January 1993

to

The U.S. Department of Education
Washington, D.C. 20202

from

The Johns Hopkins University
Applied Physics Laboratory
Johns Hopkins Road
Laurel, Maryland 20723

EC304147

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1. SUMMARY RESULTS

Following receipt of Grant No. H180C00007-91 from the U. S. Department of Education under its Technology, Education Media and Materials for the Handicapped Program, the interdisciplinary team of educators and computer professionals at Johns Hopkins achieved, and in several cases exceeded, all the objectives set forth in the specifications. This was made possible, in part, through the use of a powerful Multimedia Rapid Prototyping Tool (MRPT) used in the specification, design, and test phases of the project.

GOALS

The stated goal was to design, create and evaluate advanced multimedia instructional modules "in the areas of social studies, critical thinking skills across the curriculum, and life skills."

PROJECT ACCOMPLISHMENTS

Twelve computerized lesson paradigms (benchmarks) capable of providing multimedia instruction for students with learning disabilities have been created. These lessons are designed to provide instruction in 22 thinking skills areas. An emphasis is placed both on the development of metacognition and the cross-curricular application of thinking skills. The general approach focuses on "learning by doing" and problem solving. Additionally, two other modules were developed to assist students with mild to moderate disabilities develop life skills required for planning, scheduling, and shopping for meals. This multimedia benchmark is accompanied by a library of over 300 high resolution pictures of meal items.

A key feature of the program was the application of the APL-developed Multimedia Rapid Prototyping Tool (MRPT). This software enables a design team to preview special education software in real time and make any adjustments that are necessary. Its output is a dynamic specification that has been thoroughly scrutinized before the product is committed to code.

Continuing research and ongoing evaluation from local, state, and national experts monitored the progress of the project to ensure the soundness of design and educational effectiveness. Additionally, the project designs were demonstrated at local and national conferences, including two international conferences of the Learning Disabilities Association, where the programs were exposed to teachers, parents, administrators, and students. The constructive criticism gained from this experience proved invaluable when finalizing the designs.

2. EDUCATIONAL SCOPE

Early in the project, seven overarching principles were identified as critical to the successful integration of multimedia into the school curricula. These principles served as guidelines in the development of all the project modules and are summarized below:

1) Establish learning objectives (knowledge)
2) Define learning process to be addressed (skills)
3) Apply skills in meaningful contextual situations
4) Insure that multimedia provides true 'value added'
5) Provide flexible lesson design tool
6) Capitalize on broad spectrum of multimedia source material
7) Insure ease of use.

The basic tenet of the program was to apply multimedia technologies where they presented clear and verifiable advantages over traditional methodologies. The learning objectives had to be clear; the thinking skills had to be applied in contextual situations that were realistic and meaningful to the students; and the programs had to be easy to use by the students and the teachers involved. The generalizable educational needs and the corresponding system requirements are summarized in Table 1.

The Critical Thinking and Social Studies Modules were directed towards improving thinking skills in children with Learning Disabilities at the Upper Elementary/Lower Intermediate school levels. The skills range from basic organizational skills to the application of higher order thinking through problem solving. The lessons are not intended to focus on factual knowledge. Rather, they aim to develop skills in students that may be applied across the curriculum. Problems are

EDUCATIONAL NEED	SYSTEM REQUIREMENTS
SUPERIOR INSTRUCTIONAL VALUE	HIGH INSTRUCTIONAL CONTENT
EASY FOR TEACHER TO LEARN AND USE	"FRIENDLY", MENU DRIVEN MODEL LESSONS PROVIDED
PRESENTATION IN VARIETY OF MODALITIES	INTEGRATION OF MULTI-MEDIA COMPONENTS
INDIVIDUALIZED TO SPECIFIC STUDENT NEEDS	TEACHER CAN VARY CONTENT AND MODALITIES
RECEIVE CONSTRUCTIVE EVALUATIONS	TUTORIAL FEEDBACKS
STUDENT INVOLVEMENT AND CONTROL	TEACHER-SELECTED STUDENT INVOLVEMENT
ADAPTIVE TO STUDENT PERFORMANCE	TEACHER-SELECTED ADAPTIVE BRANCHING
EFFECTIVE PERFORMANCE ANALYSIS	PERFORMANCE HISTORY AND OVERALL SCORING

Table 1. Educational Needs and System Requirements

presented that require the student to apply basic mathematical skills and inferential thinking skills, as well as the skills traditionally associated with a Social Science curriculum.

The lessons include a multimedia project template that may be used to develop critical and higher order thinking skills in students who can benefit from a cross-curricular interdisciplinary approach to learning.

The Life Skills modules are designed for students with mild to moderate disabilities who need to develop the cognitive and organizational skills that are needed to plan meals and do shopping. This module also serves as a tool to assist the student as well as a teaching aid.

3. INTERDISCIPLINARY TEAM AND TASK TEAMS

The overall organizational structure of the project is shown in Figure 1. The project plan called for exposing the designs to teachers, administrators, students, parents, and representatives from the computer industry and world of work at all stages from concept to completion. Combined with the ability to develop rapid prototypes, this approach provided the team with early evaluation of the methods used and a very broad spectrum of expert opinion.

The work was conducted by an interdisciplinary team of educators, computer scientists, system designers, video specialists, classroom teachers, and school administrators. Early designs were demonstrated at major conferences, such as the Learning Disabilities Association's international conference, as well as local workshops, and prominent educators and technologists were invited to attend the bi-weekly meetings of the team.

The project identified 7 key issues that needed to be addressed and special task teams were formed to address each of these issues. Table 2 describes lists the teams with an outline of their main responsibilities. The teams were deliberately designed to have overlapping responsibilities so that issues could be viewed from a variety of points of view. These teams met regularly during the course of the project, reporting directly to the bi-weekly meetings of all people working on the project.

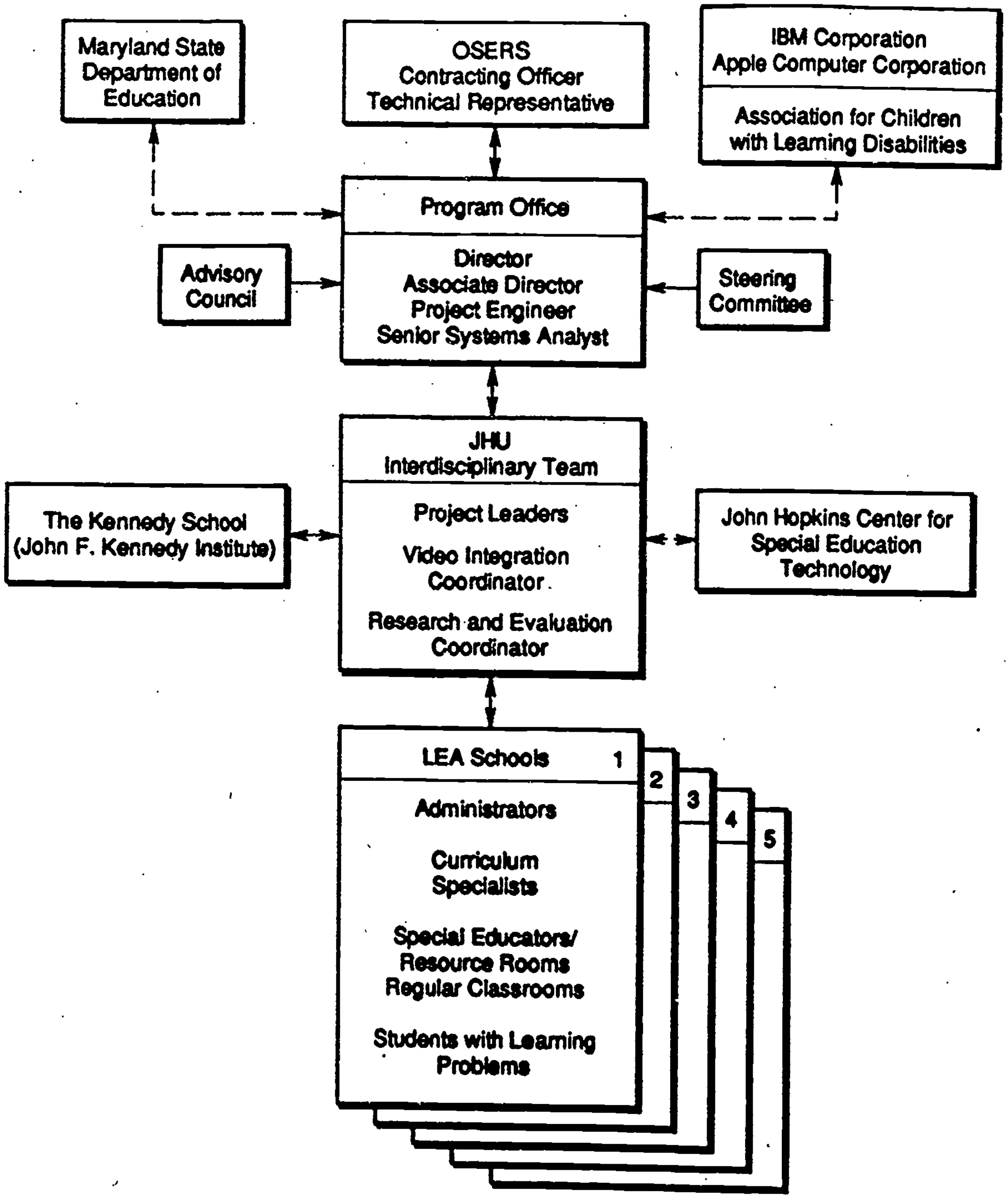


Figure 1. Project Organization

TABLE 2. MACS III TASKS AND TASK TEAMS

I. Data and Library Collection **D. TOBIN, G. Ross, P. Keen, G. Church, S. McPherson, H. Carter, K.P. Yang, L. Craig**

1. Acquire, maintain, and update publications, announcements, advertisements, other descriptions of multimedia hardware and software components, systems, software and educational materials such as CD ROM encyclopedias, video libraries, etc.

2. Flag items for potential acquisition of best of the above initially and from time to time during course of grant.

II. Software and Hardware Tools for Designing, Making and Presenting MM CAI
B. BUCHANAN, D. Tobin, G. Ross, S. McPherson, K.P. Yang, H. Carter, P. Keen

1. Authoring systems and utilities, e.g. Visual Almanac for Macintosh, Multimedia Shell for IBM PC

2. Hardware - digitizers; CD ROMs; video systems, e g. SONY View, Infowindow; networking equipment; viewing and projection systems and devices.

III. Architectures **A. KOSSIAKOFF, G. Schiffman, G. Church, M. Kercher, V. Rosskamm, D. Carran, K.P. Yang, L. Biggie, H. Carter**

1. Classroom - student presentation options, e.g. networking, student teaming, single station, etc.

2. Authoring/Editing - Scenarios and methods for constructing and presenting lessons - simple, complex and "just right" systems.

IV. Curriculum and Lesson Specification **G. SCHIFFMAN, G. Church, J. Skarbek, B. Buchanan, M. Kercher, V. Rosskamm, D. Tobin, S. McPherson, P. Keen**

1. Assess educational needs in terms of unique advantages of multimedia educational materials and resources.

2. Develop benchmark lessons that make optimal use of multimedia, e.g. in terms of MM power, application to critical student learning - reading and life skills, and repurposing of video/CD ROM resources to maximize lessons from few resources.

V. Multimedia Rapid Prototyping Tool **L. BIGGIE, K.P. YANG, R. Grauel, R. Hendrix**

VI. Lesson Design Tool(s)
Teacher Tools **P. KEEN, S. MCPHERSON, G. Church, M. Kercher, V. Rosskamm**

Develop software tools to optimize multimedia adaptation of lessons.

VII. Field Test and Research **D. CARRAN, G. Schiffman, G. Church, M. Kercher, V. Rosskamm, G. Ross, J. Skarbek, P. Keen**

4. ASSESSMENT OF MULTIMEDIA TECHNIQUES AND METHODS

The Johns Hopkins interdisciplinary team conducted a thorough assessment of all the important techniques currently being used in multimedia computing. Task teams were formed to study innovations, such as computer controlled full motion video, digitized and synthesized audio, video capture and display, and color image scanning. Work was conducted and evaluated on a large variety of computer platforms and multiple levels of technology were employed. The multimedia rapid prototyping capability allowed the team to compare the effectiveness of different approaches to the same problem. For example, when live video was required, an assessment could be made to examine the comparative effectiveness of computer animation, computer-controlled videotape, and interactive videodisc.

DIGITAL VIDEO

Digital video, such as Apple's QuickTime and Microsoft's Video, is a particularly promising development in multimedia educational computing. This technology enables full-motion video to be stored on a digital storage device, such as a hard disk. The video can then be played on a computer system without external video devices. Although this technology is still in its relative infancy, the team concluded that digital video was mature enough to be incorporated into this project and will be central to many significant multimedia projects in the future.

OPTICAL STORAGE

The RFP called for consideration of optical storage devices, and our proposal discussed the potential use of read-write magneto-optical storage devices. Work was conducted using CD-ROM's, videodiscs, magneto optical devices, and computer controlled audio stored on regular compact disks. However, it was recognized that, although promising, magneto optical devices were slow, and could not be used for multimedia applications where rapid data transfer was necessary. During the past three years, the data transfer rate of these devices has increased while the prices have decreased. In particular, the 3.5-inch magneto-optical disk drive, with its ability to write as well as read data at a reasonable rate, proved to be very useful in combining the large storage capacity of a CD-ROM with the portability and flexibility of a floppy disk. The team made extensive use of this storage medium, and sees that this technology will play an increasingly widespread role in multimedia education.

OVERARCHING SYSTEM FEATURES AND SOFTWARE REQUIREMENTS

Table 3 identifies the features that were considered necessary components of successful multimedia educational programs. Consideration of these features was prioritized in all the modules developed in the project.

SYSTEM FEATURE	SOFTWARE REQUIREMENT
"FRIENDLY," MENU DRIVEN	SIMPLE, STANDARDIZED MENUS DEFAULTS FOR ALL CHOICES
INTEGRATION OF MULTIMEDIA COMPONENTS	"PACKAGE" HANDLING OF MEDIA SEGMENTS, STANDARD FORMATS
TEACHER CAN VARY CONTENT AND MODALITIES	TEACHER SELECTED CONTENT AND MODALITIES WITH DEFAULTS
TUTORIAL FEEDBACKS	AUTOMATED FEEDBACK GENERATION LOOPING FOR WRONG ANSWERS
STUDENT INVOLVEMENT AND CONTROL	TEACHER SELECTED STUDENT HELP AND EXPLORATORY MODES
ADAPTIVE TO STUDENT PERFORMANCE	BRANCHING OF LEVEL BASED ON STUDENT PERFORMANCE
PERFORMANCE HISTORY AND OVERALL SCORING	STEP-BY-STEP RECORD GRAPHIC SCORE DISPLAY

Table 3. Overarching System Features and Software Requirements

5. MULTIMEDIA RAPID PROTOTYPING TOOL

Working with complex computer systems at the leading edge requires early evaluation of techniques, particularly where a widely diverse interdisciplinary team is involved. This phenomenon was further intensified since it is recognized that the future of CAI depends largely on the success of embedding the large corpus of educational knowledge into computer-assisted instruction programs. Frequently, an expert in instructional techniques is not necessarily well-versed in cutting edge technology, and conversely, multimedia experts are not necessarily familiar with the full range of instructional techniques. The Hopkins team recognizes that the critical challenge to multimedia software developers remains the optimal matching and use of a wide variety of experts. Properly managed, each individual talent can become leveraged and multiplied. To achieve this leveraging effect, an important tool was used in the creation of these benchmark lessons, the JHU-developed Multimedia Rapid Prototyping Tool (MRPT).

Developed prior to the grant under internal Johns Hopkins funding, the MRPT enables an interdisciplinary team to preview a special education program before it is committed to code. The interdisciplinary team met biweekly to review progress, and during these meetings, the MRPT allowed members of the team to visualize and dynamically run a model of the proposed software. This design was displayed on a large screen in the presence of all members of the team, who were thereby able to specify the design and see it implemented on the spot. The team then interacted with the program in real time to assess the ease of use, educational approaches, and screen design. The team made tradeoffs and allowed a wide variety of people to examine the proposed designs and exercise the software. When the design had been thoroughly scrutinized, it was then coded. This method proved invaluable in leveraging the creativity and productivity of the interdisciplinary team. Additionally, preliminary field evaluation was conducted and changes could be made without the expensive penalty of altering low-level computer code.

The MRPT is described in detail in Appendix I.

6. SYSTEM DESCRIPTION

The Multimedia System is divided into two components: Social Studies and Critical Thinking, and Life Skills. The Social Studies and Critical Thinking benchmarks were designed to run on a Macintosh computer, and the Life Skills benchmarks were designed for the MS-DOS compatible computers with a 386 SX (or better) microprocessor.

SOCIAL STUDIES AND CRITICAL THINKING

Table 4 provides an overview of the twelve lessons designed for students with learning disabilities. It links the thinking skills that have been addressed to each of the lesson modules (shown horizontally at the top of the table).

A description of each of the lesson benchmarks follows. The description of each benchmark contains the objectives of the benchmark; a description of the student's interaction; and a section that provides further details, including educational, technical, and other issues of concern.

MULTIMEDIA DIRECTIONALITY AND GEOGRAPHY PROJECT

Objectives

A typical social studies curricular framework includes provision for a case study in which students spend an extended period focusing on a particular country or state, gathering and interpreting as much information as possible. For example, most states include a period where the social science curriculum concentrates on their home state. The overall objectives of the case study approach fitted in neatly with the overall approach of the multimedia project and it was decided that it was appropriate to develop a software template to complement this kind of activity.

SKILLS / BENCHMARKS	Multimedia Geography Projects	Designing Highway Signs	Planning Alternative Routes	The World	Time Zones	Latitude and Longitude	Estimating, Calculating, and Looking Up Distances	Identifying the Directions of Routes	Identifying the Routes by Direction	Index - Using an Index on a Map to Locate Places	Grids - Identifying Locations on a Grid	Map Attack - Recognizing Key Elements of a Map
Classification	X								X			
Organizational Skills	X	X		X		X			X	X	X	X
Inferential Thinking	X	X			X							
Understanding Graphs and Tables	X	X			X	X	X				X	X
Matching Textual to Graphical Rep. of Data	X	X			X						X	
Using Tools for Problem Solving	X	X	X		X	X	X					X
Interpreting Visual Data	X	X	X	X	X	X	X	X	X			X
Information Gathering Skills	X	X	X									
Understanding Compass Points				X				X	X			
Interpreting Maps	X						X	X	X			
Spatial Thinking				X	X	X		X	X			
Estimation							X					
Intercultural Understanding	X			X								
Considering Alternatives	X		X									
Decision Making	X	X	X									
Comparing and Contrasting	X				X							
Drawing Conclusions Deductive Reasoning	X	X	X		X							
Cause and Effect Principles	X	X										
Forming Generalizations	X	X								X		
Process of Elimination			X									
Relevance and Irrelevance	X											
Building Tools for Problem Solving	X	X	X									

Table 4. Thinking Skills Addressed in Social Studies/ Critical Thinking Modules

In particular, the case study proved to be an ideal vehicle in which to apply critical thinking while crossing traditional curricular boundaries, one of the stated objectives of the project.

The Multimedia Directionality and Geography Project template is designed to complement an existing social studies extended case study, such as the study of Maryland, which is part of the curriculum for fourth grade in Maryland, where this template was field tested. The overall objectives of such a case study typically include the following:

<u>Objectives</u>

Students will:

Locate and interpret major cultural and physical features

Obtain, interpret, evaluate, organize and use information from observing, investigating, listening, and reading

Obtain, interpret, evaluate, organize and use information from maps, charts, globes, graphs, and tables

Identify key economic, social, ethnic, and cultural factors and understand their influence on a state or country

Identify key events and their influence on a state or a country

Work in teams or other cooperative learning arrangements to gather, interpret, organize and evaluate data

Apply skills learned across the curriculum to develop an extended "case study" project.

The Multimedia Directionality and Geography Template is designed to enhance the case study work. Accordingly, all the above objectives are also central to this benchmark. In addition to the objectives stated above, a computer-based case study fosters the following outcomes:

Students will:

Use multimedia for optimal expression of ideas

Apply computer skills for academic purposes

Present information in a way that other students can learn

Present data to facilitate visualization of concepts

Understand political and geographical hierarchies through "zooming" from the world to a country or state.

Student Interaction

The students gather relevant information using graphs, tables, pictures, video materials. With guidance from a teacher and/or a media specialist, the students enter these materials into the computer. Interfaces and drivers were developed or integrated as appropriate for the following computer peripherals: a color scanner, a SuperMac Video Spigot (digital video input device), and MacRecorder (speech digitizer).

Once the materials are entered into the computer, they are organized into a presentation that combines graphic displays, digital video (QuickTime), charts, graphs, text. Also, there is provision to provide the students with the opportunity to ask questions to monitor the viewer's understanding of the presentation.

Further Details

This benchmark allows students to develop multimedia projects based on geographical case studies that regular curricula require. The template provides an easy interface that allows students to create, edit, and integrate multimedia effects without the need to program or even know very much about the computer. The purpose of the program is to foster the development of higher order critical thinking skills through cooperative project development.

The RFP called for "prototypical" programs that took advantage of the effects of multimedia. The Multimedia Geography Project program represents a somewhat experimental approach, differing in many respects both in technology and educational approach from the isolated student format common with computer-assisted instruction. For example, instead of working alone with the computer, this program requires the student to work as a member of a team. Instead of watching presentations and following instructions, the student creates the presentations and the instructions.

In one of the schools in Baltimore County, where this program was field tested, the principal suggested that a further division of teams was appropriate. The teams were organized into two groups, each of which was responsible for half of the curricular content. Each team was responsible for gathering the appropriate materials and for presenting it in such a way that the other students would learn the information. This approach provided each team with a clearly-defined focus. (Figure 2 is an actual example of the work of a team of fourth grade students working on the various land forms in Maryland.) The student team conducted the research, scanned and scaled the map, and keyed-in the text.

Although the Multimedia Directionality and Geography Project is designed to require minimal computer skills, it requires that the teacher organize the students into teams for the

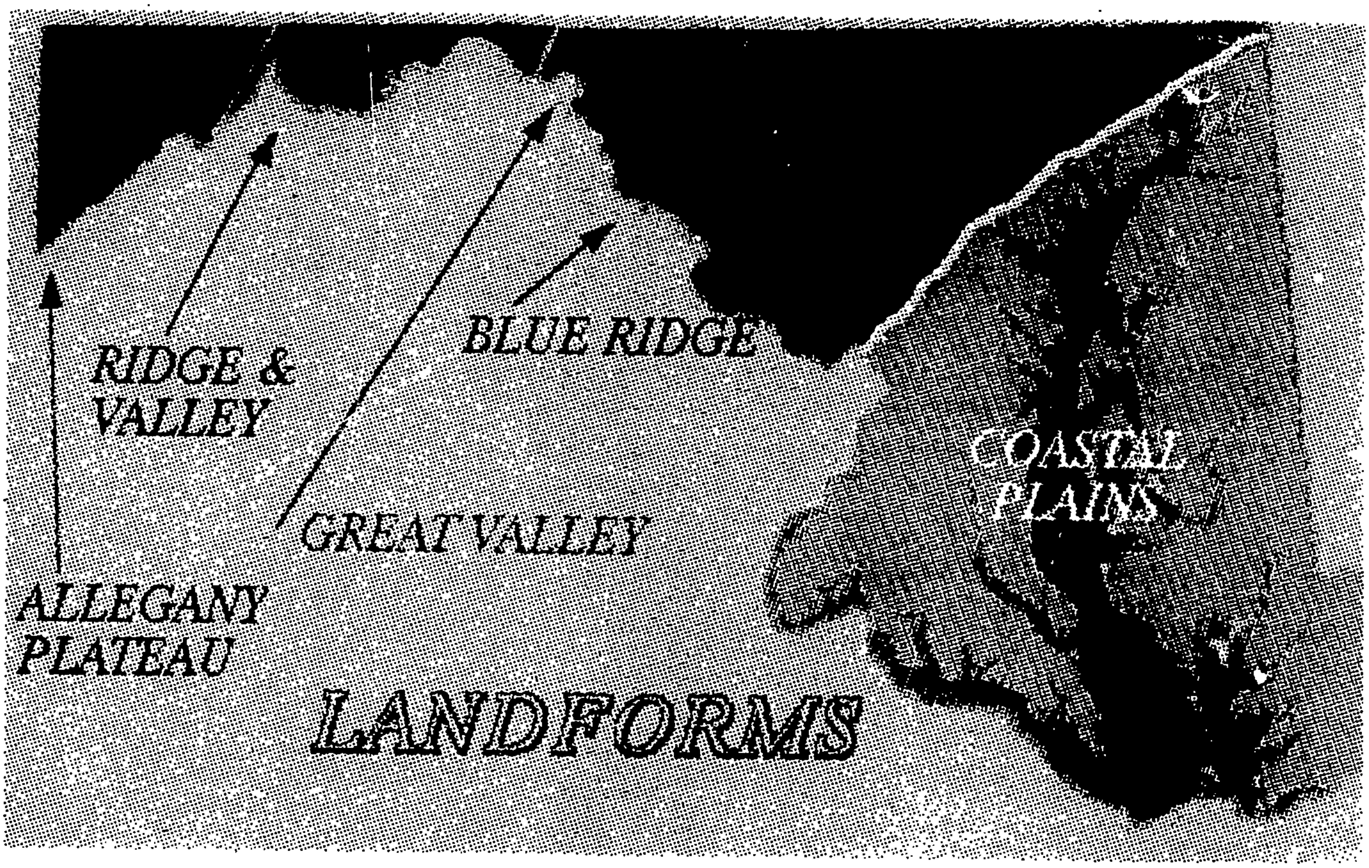


Figure 2. Map created by team of 4th grade students at Relay Elementary School.

Theresa Reininger, Age 9 (Birthdate - 9/21/83)
Robbie Alt, Age 9 (Birthdate - 10/29/83)
Katie Grace, Age 9 (Birthdate - 3/17/83)
Frank Belton, Age (Birthdate - 2/24/83)

assembly and editing of materials. The program defines a new role for the teacher as a facilitator rather than a purveyor of information.

While hardware configurations were generally designed throughout the project so that the benchmarks could be used widely on basic multimedia computer systems, the implementation of this template is enhanced considerably if the class additionally has access to multimedia input devices, including a digital video input device and a color graphic scanner. (The standard Macintosh LC is designed with a built-in speech digitizer in its basic configuration.)

The program allows the students freedom to choose whatever materials are available and appropriate, but provides a structure. Typically, the subject of geographical interest is accessed through a series of maps, starting with a map of the world and gradually zooming in to the area of interest.

Figure 3 shows a typical fourth screen of a series created through the template. Before reaching the screen in Figure 3, on the first screen, a map of the world, the user has clicked the mouse on the African continent. The second screen zooms into Africa while the third screen shows East Africa. The purpose of this structure is to provide the students with a sense of perspective and hierarchy. Hence, the miniaturized maps at the bottom left of the screen indicate how the current map was reached.

At the top of the screen the student is provided with several tools in the form of "pull down" menus. These include system tools that are available in the Macintosh operating system, Hypercard tools, such as the "Go" menu, and tools that have been specially incorporated into the Multimedia Geography Project Benchmark. The "Help Tools" provide computerized versions of tools that typically help students in Social Studies, and are provided as appropriate to the context, but typically may include a calculator, a scale, and a compass rose. The message menu includes

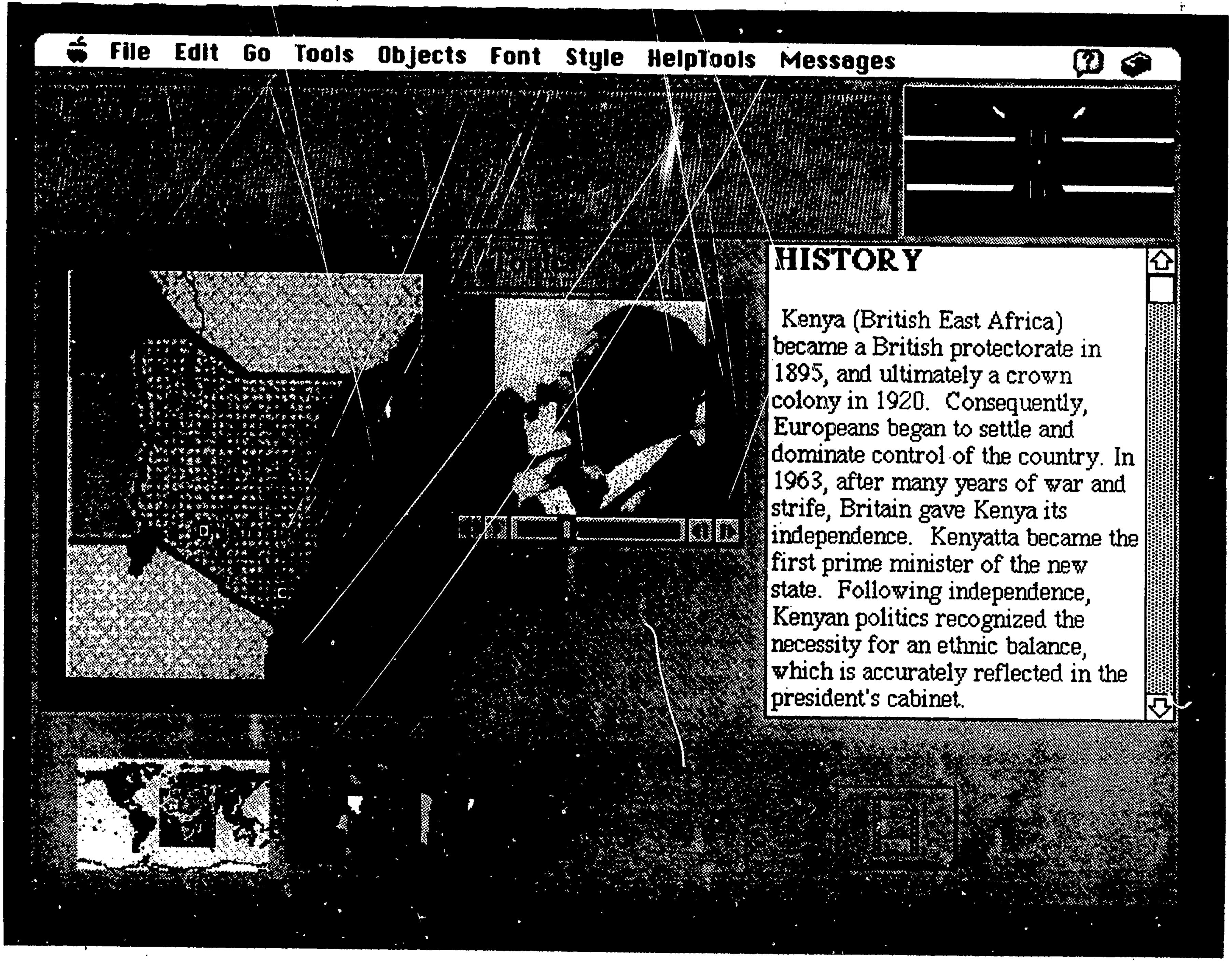


Figure 3. Screen created using Multimedia Geography Project template.

questions, instructions, feedback, and are available on demand rather than permanently displayed.

A "pull down" menu entitled "Topics" allows the student to view items, including government, history, topography, the arts, education, industry, climate, and so on. The currently selected topic is History, which is displayed in a textual format on the right hand side of the screen. Also, the film clip has appeared beneath the text field on history. This indicates that a film clip is available to support the text. When pressed, a digital video film (QuickTime) that includes audio is displayed on the screen. The action of the current film clip has been stopped and sent to the printer during a video frame portraying Kenyatta. At the top right hand side of the screen is the Kenyan flag.

DESIGNING HIGHWAY SIGNS

Objectives

Students will:

Identify a location on a map based on a written description

Plan routes

Transpose directions on a map (north, south, east, west) to directional indicators on a sign (left, right, straight ahead)

Sequence instructions on a sign in a logical order.

Student Interaction

The student is presented with a map and is required to create an appropriate road sign for a particular location and direction. Using map reading skills, the student identifies the location on the map and fills in the template for a sign. In the sample lesson in Figure 4, the student

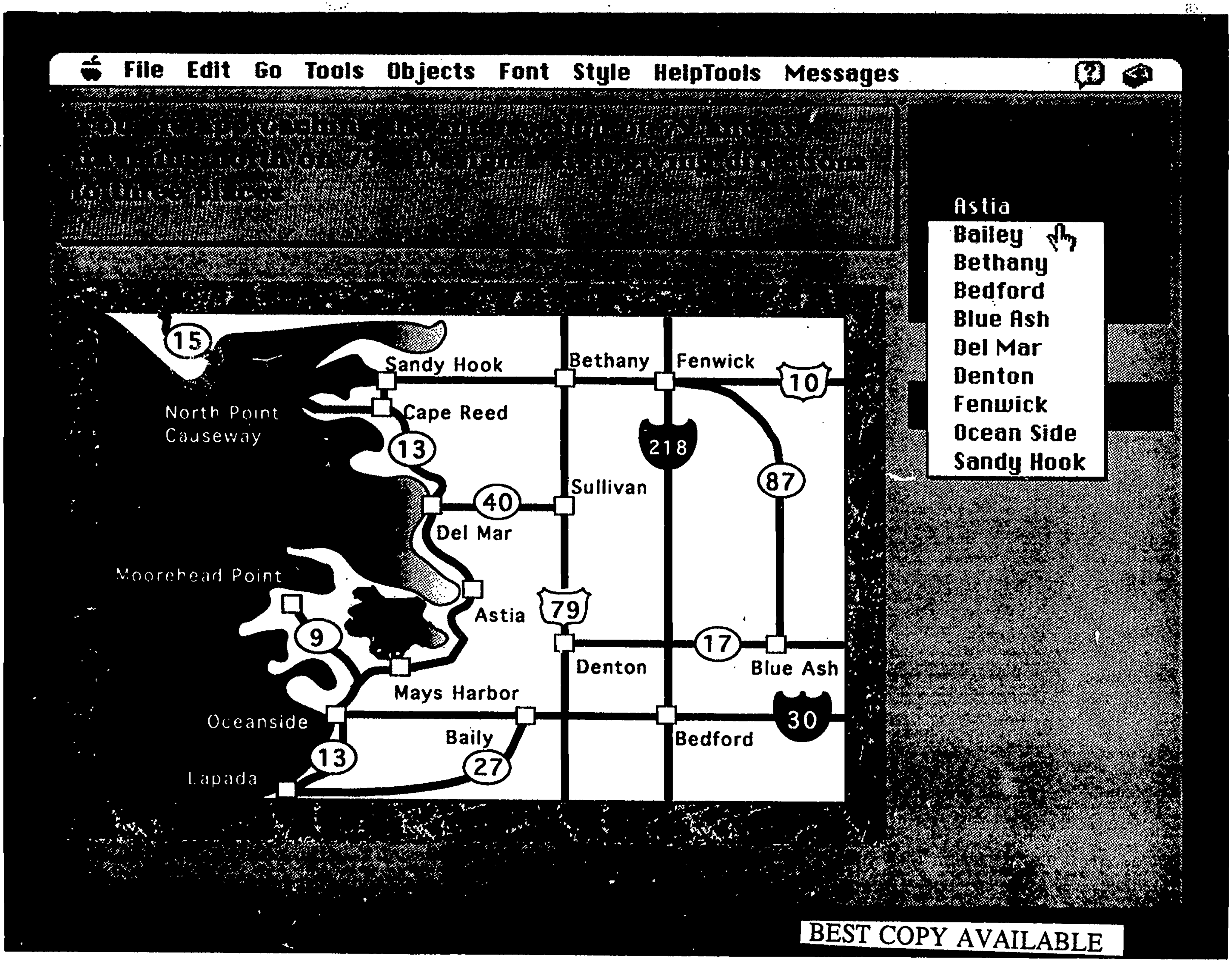


Figure 4. Using directionality skills to design highway signs.

needs to identify three places, Bethany, Sandy Hook, and Fenwick, and three directions. Bethany is straight ahead; Sandy Hook requires a left hand turn; Fenwick a right hand turn. The place names are accessed through "pull down" menus, as shown in the screen capture in Figure 4. The direction of the arrow is changed by clicking on the question mark button, which cycles through each of the available directions. When the sign is completed, the student presses the "Finished" button using the mouse.

Further Details

This benchmark is an advanced directionality program and the example of this benchmark depicted in Figure 4 is illustrative of many of the principles that underlie the approach to the whole project. First, the student engages a "learn by doing" approach, creating a product rather than simply producing an "answer." In this case, the task is to create a sign for a highway that indicates the direction of certain routes. Secondly, the principle that understanding is accomplished when it is necessary to demonstrate that understanding to someone else is achieved since the design of a sign involves an explanation of a problem.

Finally, the paradigm allows for a great deal of flexibility in learning level. For example, although the benchmark indicated shows routes running from south to north, and the student's task is essentially to transpose those directions into left and right instructions, using the same paradigm, other examples were created where the routes ran north to south, east to west, and west to east. These cases represent a much more difficult problem and provide an avenue for the student who succeeds with the initial representation.

The student is provided with feedback that is sensitive to the context. For example, where appropriate, the program analyzes the sequence of place names chosen, and will provide feedback in both text and voice. If a student chooses the places correctly, but fails to place the arrows correctly, the computer is sensitive to the fact that the problem lies in the ability to transpose cardinal compass directions rather than to read a map and provides appropriate text and/or voice feedback.

PLANNING ALTERNATIVE ROUTES

Objectives

Students will:

Identify a location on a map based on a written description

Plan routes

Transpose directions on a map (north, south, east, west) to directional indicators on a sign (left, right, straight ahead)

Sequence detailed instructions on a sign in a logical order

Consider and propose alternative solutions

Interpret and follow complex directions.

Student Interaction

Presented with a map, a student is told that part of the road is closed between two points. The student is presented a message, such as:

You are a road engineer. I-418 is closed for repairs. Make a sign to place at Harrison to help direct people traveling to Logan.

Using pull-down menus, the student has to design a sign, or in a more complex problem, a series of signs to enable a motorist to go from one place to another when the most direct route is not available. Two decisions need to be made in the creation of a sign: (1) what alternative route should be taken, and (2) what direction should be taken.

Further Details

This problem exercises a student's problem solving skills and allows the student to exercise a degree of creativity in designing a route other than the obvious one that the program states is closed for repairs.

The screen capture in Figure 5 has been made after the student has submitted an answer to the question quoted above, and some feedback has been provided. Although the student's attempt at the answer is wrong, there is some merit in it since the direction is right and the destination is also correct. The feedback, which is delivered through voice as well as text, tells the student that the destination (Logan) is correct, but that Route 26 does not go through Harrison. The student is given another attempt to solve the problem before being provided with a correct solution.

THE WORLD

Objectives

Students will:

Interpret a map of the world

Identify the continents

Identify the oceans

Identify major countries

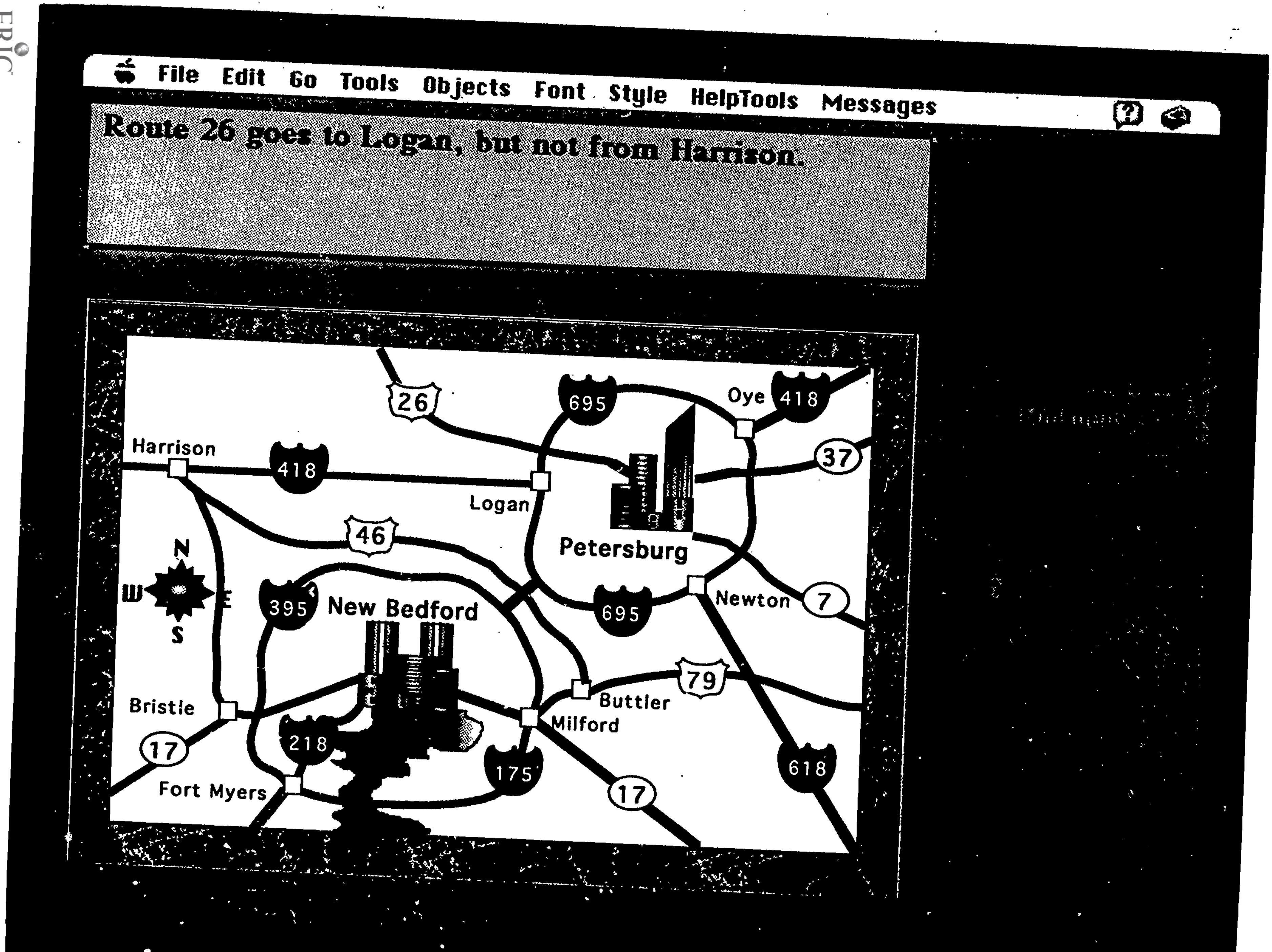


Figure 5. Planning Alternate Routes -- Student feedback after wrong answers.

Identify major features as defined by teacher or facilitator (Tropic of Cancer, Equator, Tropic of Capricorn)

Use cardinal and intermediate compass points to assist in locating items on a map.

Student Interaction

The student is asked to identify key features, continents, or countries on the map as specified by the teacher or facilitator. The system allows for feedback to be delivered in terms of direction, for example, "Try farther West." When the student provides the right answer, the place is labeled and the next question is asked.

Further Details

The items to be asked can be easily changed, thereby providing a flexible template for students to learn where places are, and to locate them using the cardinal and intermediate compass points for guidance.

TIME ZONES

Objectives

Students will:

Identify major time zones

Calculate the time in different places according to time zones

Solve problems that involve time zone calculations (making travel plans, telephone calls, etc.).

Student Interaction

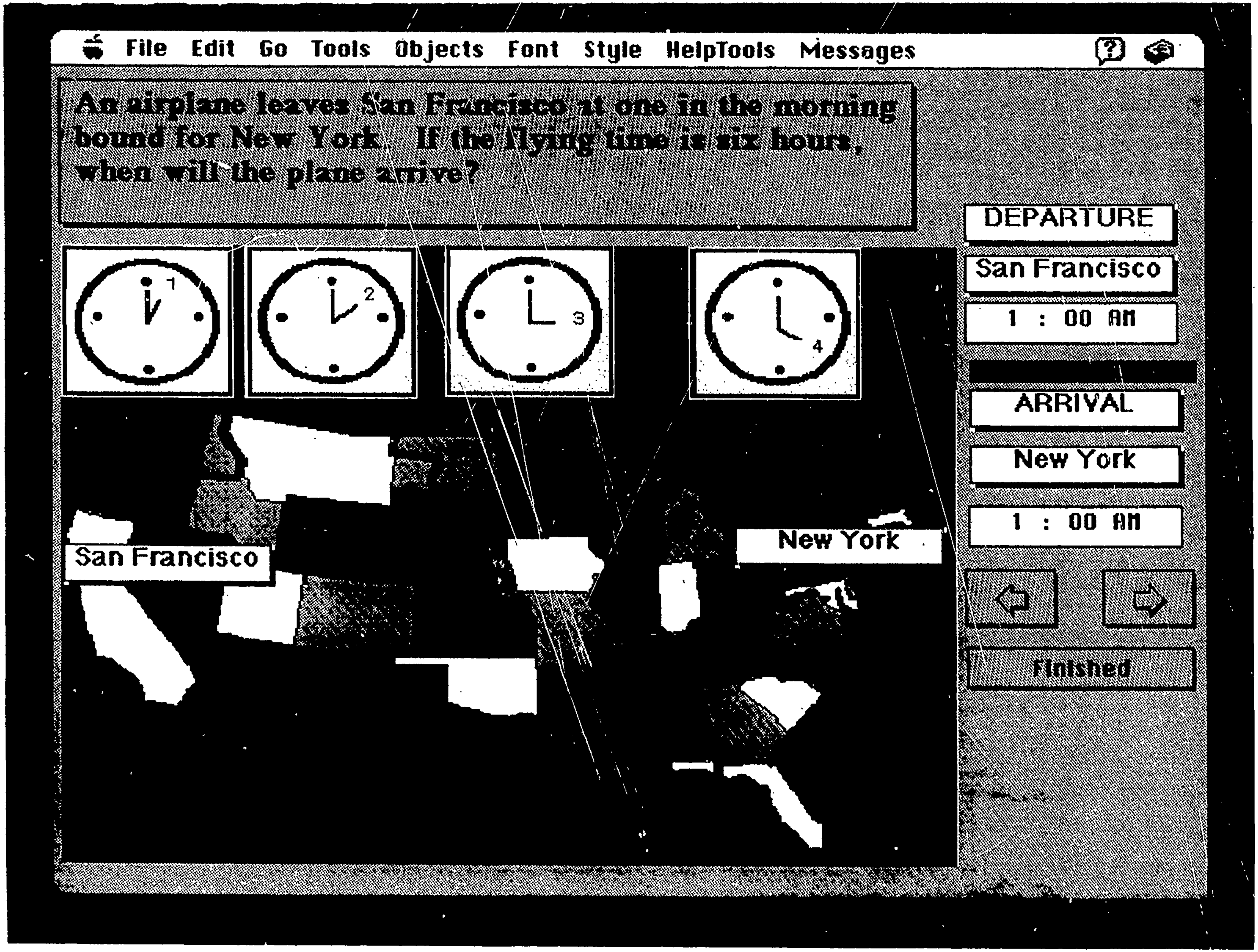
The student is faced with one of two classes of problem. The first involves a simple calculation. For example, given a map that indicates time zones, the student may be asked what time it is in Houston if it is five o'clock in San Francisco. Alternatively, the student may be posed with a more involved problem. Figure 6 shows an example where a student needs to add both the time difference and the duration of a flight in order to reach the right answer. The student clicks on arrows to change the time and presses a "Finished" button at the end of each problem.

Further Details

This benchmark takes the student from simple time zone calculations involving first addition and then subtraction. The next level involves problems where the time zone is a major factor, involving travel arrangements, telephone calls, and so on. For example, a child may be told that his/her grandmother likes to go to bed at a certain time each night. If the child lives in a different time zone, what would be the latest time that the grandmother may be called?

The feedback is sensitive to the type of difficulties that may be encountered. For example, in one of the travel questions, a student frequently adds the flight time correctly, but forgets to take the time zone difference into account. In other cases, the student may add where a subtraction is necessary. (The computer will pinpoint the cause of the problem for the student and provide an appropriate helpful explanation.)

Since the purpose of this program is not to test the child's calculating ability, the arrow controlling the time is designed to advance in one hour increments automatically moving from A.M to P.M., and from twelve o'clock to one o'clock. Additionally, for this exercise, the calculator becomes available among the "Help Tools" accessible through the "pull down" menu at the top of the screen.



36

Figure 6. Problem solving with time zones.

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In this benchmark, additional places may be added to accommodate cities that are not included in the original bank of major places.

LATITUDE AND LONGITUDE

Objectives

Students will:

Identify the Equator and Prime Meridian

Locate the Northern, Southern, Eastern, and Western Hemispheres

Locate specific lines of latitude and longitude on a map or globe

Use latitude and longitude coordinates to locate places on a map.

Student Interaction

The student interacts by responding to questions that deal with latitude and longitude including the identification of the Prime Meridian and the Equator. Answers are typically selected through "pull down" menus as in Figure 7, particularly where multiple correct answers are involved.

Further Details

The benchmark is designed to give the student practice in using latitude and longitude lines. The lower level questions focus on a single line, as in the example in Figure 7. As the student progresses, the questions focus on coordinates.

Feedback is delivered in voice as well as text. As in the other benchmarks, it is designed as far as possible to be "smart" and sensitive to the difficulty the student is having. For example, the most common problem associated with these exercises is for the student to confuse latitude

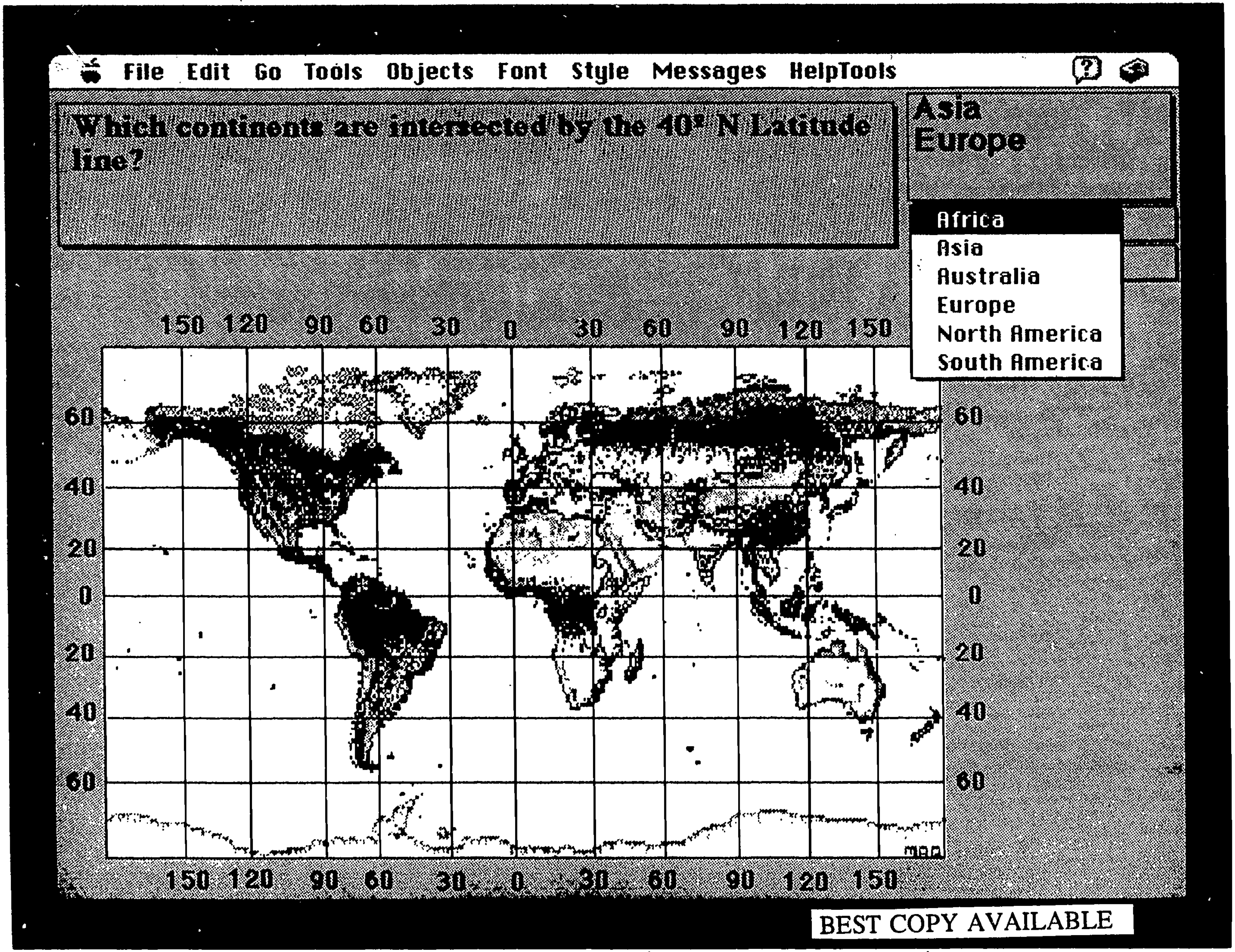

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Figure 7. Solving problems with latitude and longitude.

with longitude. The program will detect errors of that nature and help the student reach the correct answer accordingly.

ESTIMATING, CALCULATING, LOOKING UP DISTANCES

Objectives

Student will:

- Identify appropriate tools to identify and determine distance
- Use a map scale to determine and estimate distances on a map
- Look up distances on a table
- Use mileage markers on a map and a calculator to determine distances
- Understand the relationship of the map scale to actual size.

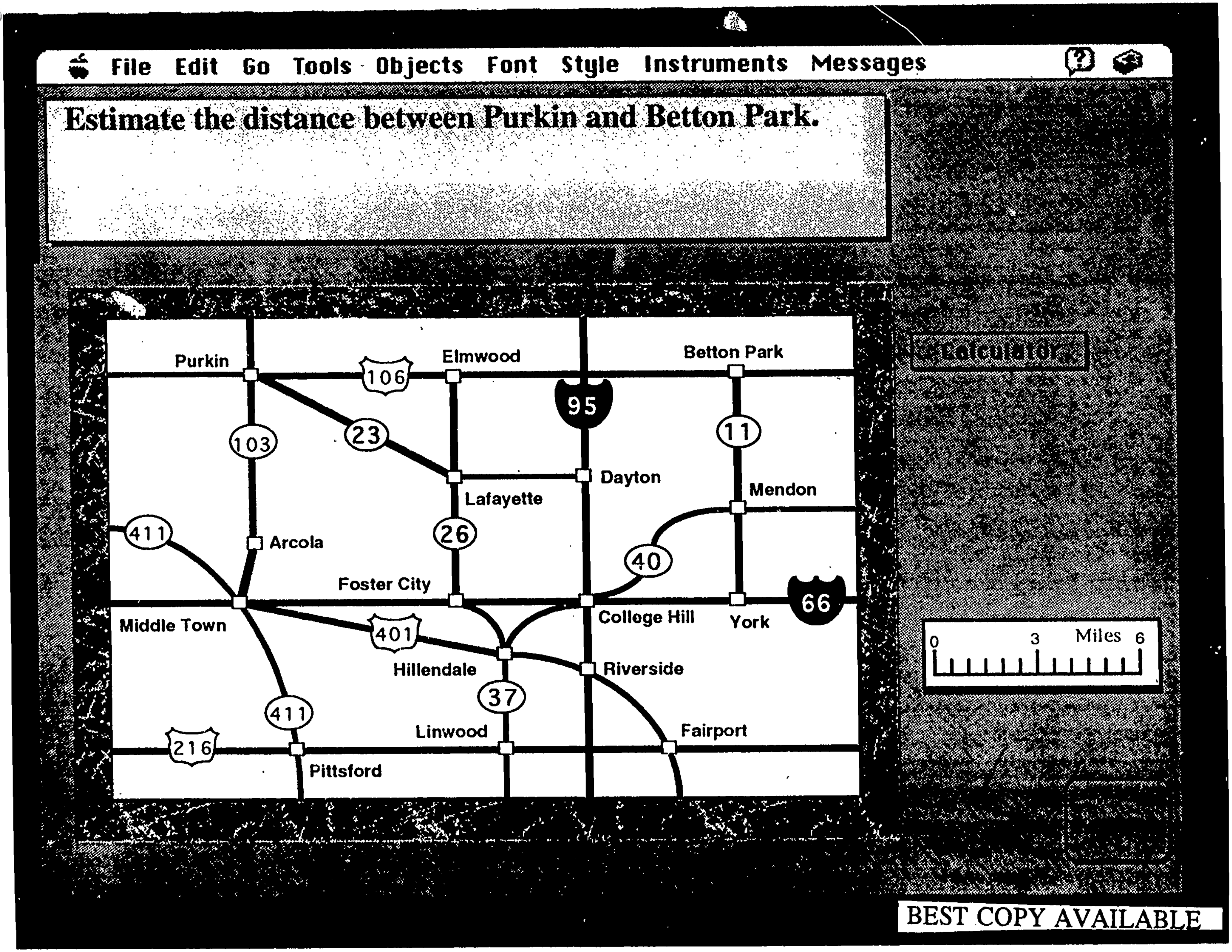
Student Interaction

Figure 8 illustrates the benchmark in which the student is asked to determine the distance between two points on a map. A variety of tools is available for assistance, including a scale, a distance table, distance markers, and a calculator.

The student may choose to use a particular tool to report the answer and has the option of verifying the answer using a different tool. For instance, the distance may be determined using the scale and verified with the distance table.

Further Details

When maps are used to calculate or estimate distances, one of three methods is usually used: a scale, distance markers on the map, or a table. The use of each tool is usually determined by the speed with which one wants to reach an answer, and the degree of accuracy



42

Figure 8. Using a scale to estimate distances.

that is required. This benchmark accommodates each of the tools and allows the user to verify an answer using an alternative tool before declaring the answer.

Frequently, the question (as in Figure 8) will ask for an estimate of the distance rather than a precise measurement, particularly as a typical scale on a real map can provide only an estimate of the answer. The program is designed to accept reasonable estimates as well as absolutely accurate answers.

The system calculator is also available as an option in this benchmark as it may be useful to the user who is using the distance markers method to calculate distances.

MATCHING COMPASS POINTS TO A GIVEN ROUTE

Objectives

Students will:

Identify a direction by looking at a route on a map

Identify cardinal and intermediate points on a compass

Decide when it is appropriate to use the compass rose as a tool to aid map reading

Transfer a verbal (written or spoken) problem into identification of routes and directions.

Student Interaction

The student is presented with a series of maps, and is required to identify the direction of these routes by entering the direction either by clicking on a compass rose or through multiple choice. The benchmark progresses dealing with both intermediate and cardinal directions.

Further Details

The purpose of this benchmark is to give the student practice in determining the directions of routes on a map. Directions are expressed in written and spoken formats to provide the student with the experience of transferring verbal information into specific applications of directionality skills.

IDENTIFYING ROUTES BY DIRECTION

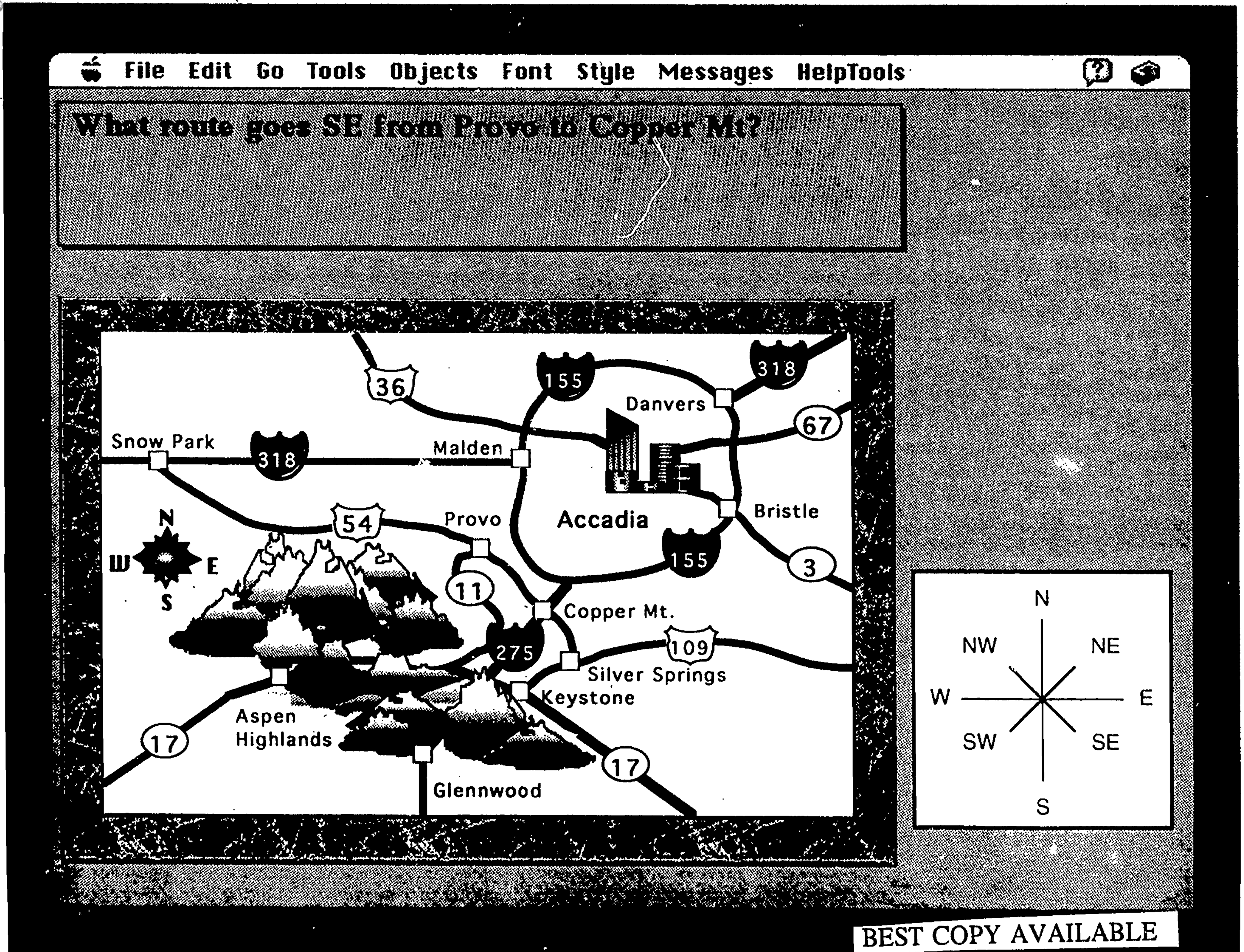
Objectives

Students will:

- Identify routes running in a given direction
- Identify cardinal and intermediate points on a compass rose
- Decide when it is appropriate to use the compass rose as a tool to aid map reading.
- Transfer a verbal (written or spoken) problem into identification of routes and directions.

Student Interaction

The student is required to identify routes given a particular direction (see Figure 9). The student responds by clicking on all the routes on the map that fit the criteria specified in the problem. Feedback is provided by visual and audio cues, in which the correct answer is highlighted on the map.



46 Figure 9. Identifying routes given a direction.

Further Details

The benchmark serves as a means for a student to gain practice in reading text or listening to an oral description, and then identifying an appropriate route. This corresponds to the real life skill in which general directions are given, but the specific route needs to be identified.

INDEX

Objectives

Students will:

Locate items on a map given their coordinates in an index

Report the location of an item on a map in terms of its location on a grid.

Student Interaction

The student is shown initially a very simple map as in Figure 10 with a simple grid consisting of four columns and four rows. (This progresses to the more complex series of maps and a more extended grid system that are used in the other benchmarks.) At the right hand side of the screen, there is an index, and the student has to locate items listed in the index using the mouse. When the student makes an error, initial prompting is achieved by highlighting the row and the column to identify the coordinate correctly. Correct answers are rewarded with the appearance of an icon representing the item on the map.

The student is also required to locate an item and then report its location in terms of coordinates.

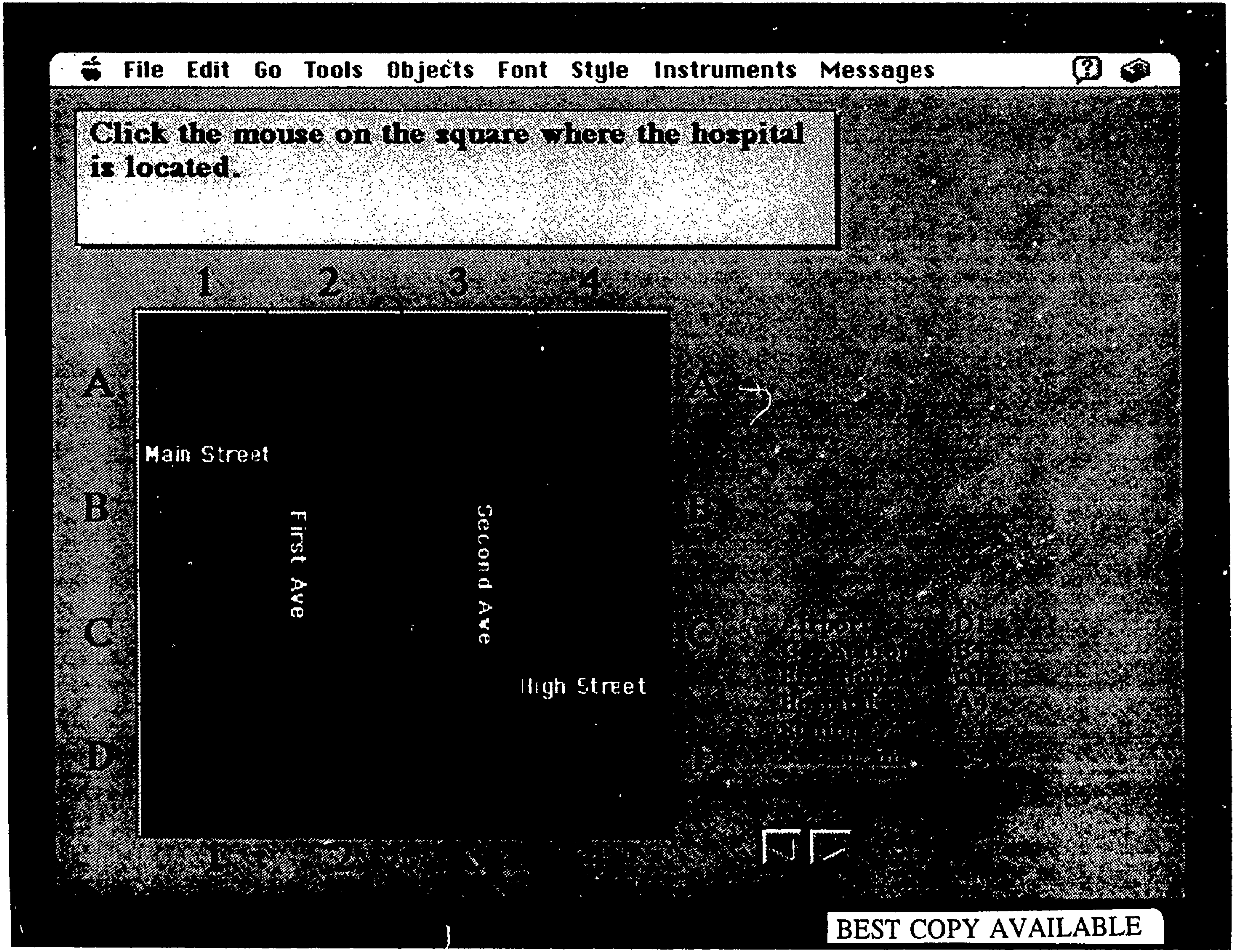


Figure 10. Using a grid and index to locate items on a simple map.

Further Details

This benchmark provides the elementary student with a means of learning to use and create an index. The student is required to both interpret an index, and create an index by reporting the location of items in terms of their coordinates on the map.

This benchmark provides a foundation (as well as a remedial path) for the more advanced lessons dealing with topics like latitude and longitude. For the student, who is having difficulty at this level, the Grid program, whose description follows, serves as a remedial mode.

GRIDS

Objectives

Students will:

Identify rows on a map

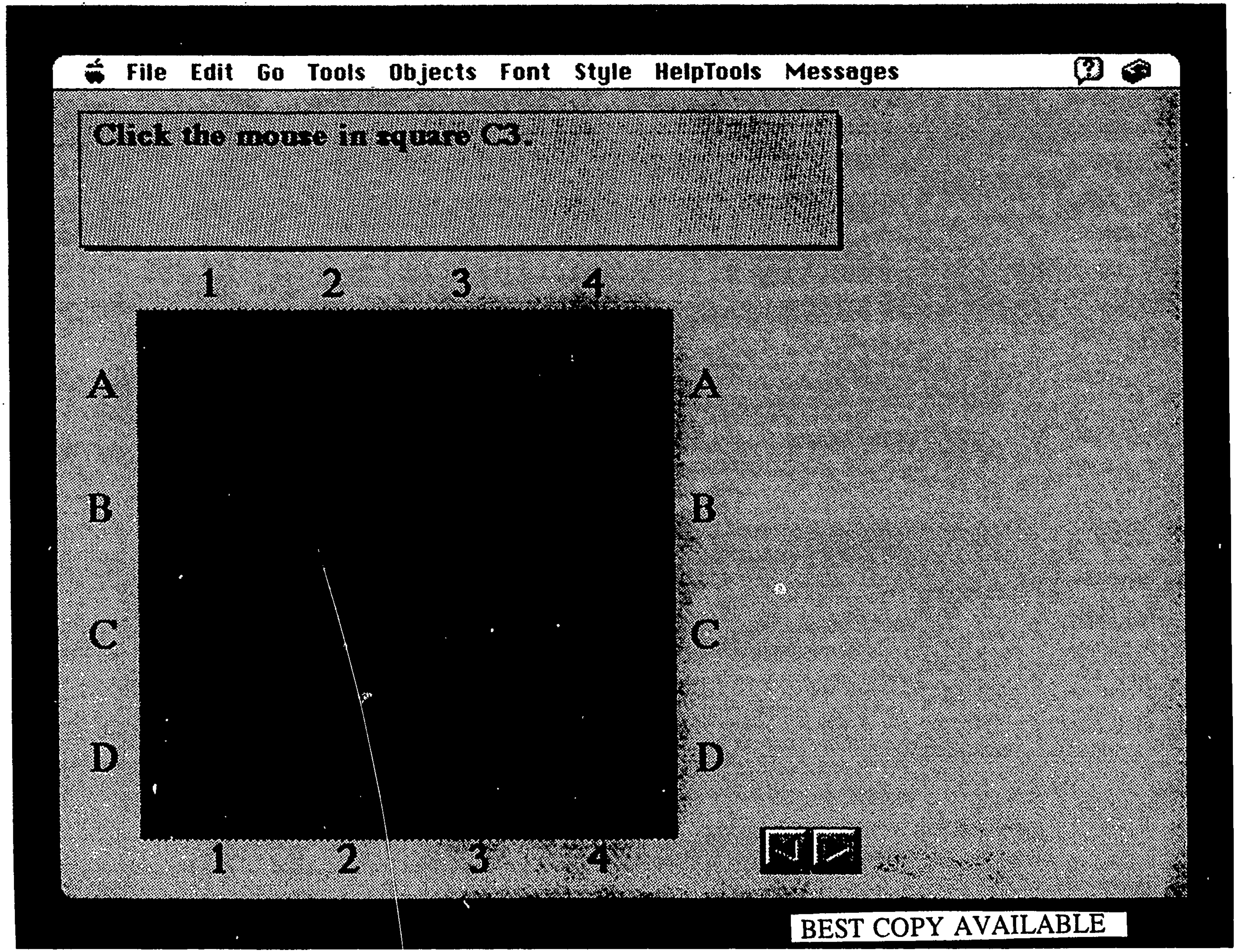
Identify squares on a map

Identify a square (a coordinate of a row and a column) on a map

Understand locations when expressed as coordinates.

Student Interaction

According to the level of difficulty, the student is asked to identify rows, columns, and squares on the map. The columns are labeled by number, and the rows are labeled by letter. The student, who is able to identify columns and rows, is then asked to identify squares, which combines both of these skills (see Figure 11).



52 Figure 11. Basic Grid: Identifying columns, rows, and squares on a simple grid.

Further Details

This benchmark serves primarily as a means of orienting the student who is having severe difficulties with maps and directionality in general. Often used as a remedial loop in the Index program, the program focuses on identification of columns, rows, and finally squares.

This benchmark recognizes that most maps have an index, in which landmarks are represented by a square on a grid, the combination of the column and row. Furthermore, an understanding of a grid organization is necessary for other map reading skills, such as coping with latitude and longitude.

At its most elementary level, this benchmark asks the student to identify a row or a column, delivering instructions and feedback in text and voice. The student uses the mouse to point at the correct answer.

MAP ATTACK

Objectives

Students will:

Identify different kinds of maps and their purposes

Identify the different tools available on a map

Understand the purpose of a compass rose, a legend, a scale

Be able to survey and scan a map.

Student Interaction

The student is asked to identify key elements on a map such as the title (see Figure 12), the scale, the legend, and the compass rose. Another question follows if the correct answer is given. Following a first incorrect answer, the feedback provides a hint. For example, "The scale

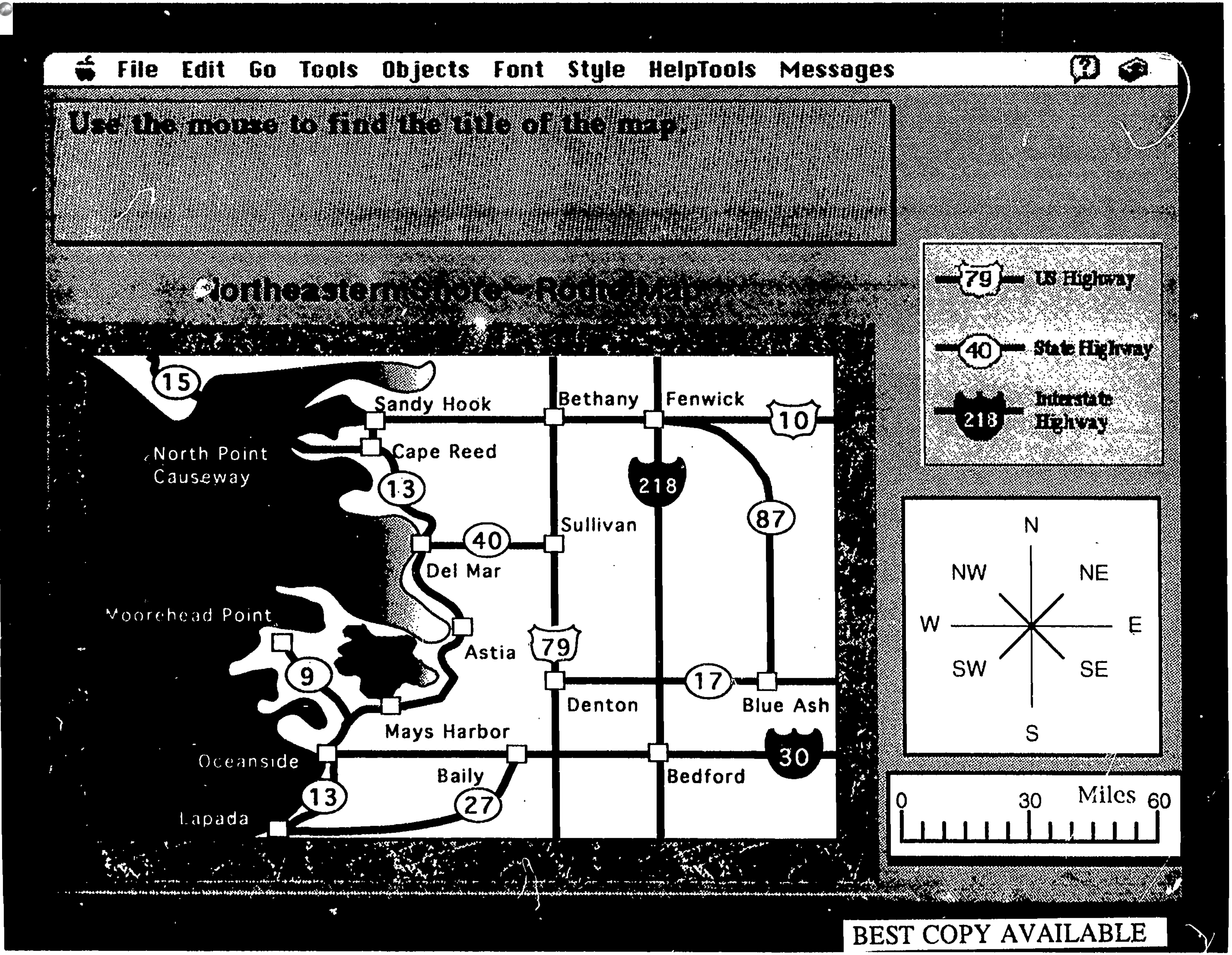


Figure 12. Identifying key elements on a map.

is used to help measure distances." After that a visual cue identifies the item, and its purpose is explained.

Further Details

The purpose is to accustom the student to surveying a map before attempting to read it. The student should first look at the title to verify that this is the map of the right place and the right kind of map. Also, it allows the student to become familiar with the tools that are used in the other lesson benchmarks. As the student advances, these tools are available on demand through the "Help Tools" pull-down menu so that a sense of their use is achieved.

LIFE SKILLS

The Life Skills benchmarks are designed to assist students with mild to moderate disabilities in planning meals, and creating shopping lists. They can be used both as a teaching tool and as a practical application for planning, creating, and storing shopping lists and menus. The system includes over 300 photo realistic pictures of food and general meal items. Sample food and meal items are located behind Figure 13.

Objectives

Students will:

Plan a menu (by meal, by the day, by the week)

Select foods presented through voice, pictures, and text

Understand the steps involved in planning a meal

Transfer meal plans into shopping lists

Use shopping lists in the grocery store.

Student Interaction

The program opens by providing the student with an option to plan menus or make a shopping list. If the student chooses to plan menus, he or she then needs to decide what the first meal should be. At the simplest level, there is the ability to simply decide on breakfast, lunch, or dinner. At a more advanced level, control is provided so that the first day may also be selected. The student is then able to select meals for one or several days, or for a whole week.

The student then is able to decide whether to select a standard meal or a "build your own" meal. The first selection is intended as a more elementary step and the student chooses from a series of set meals. For example, the hamburger is followed by ice cream for dessert, and, in this mode, there is no provision to choose a different dessert. (However, the student may, at the teacher's option, delete an item, or the teacher is able to change mode "on the fly" if necessary.)

If the student chooses a "build your own" meal, he is able to select from five categories of items from a screen (Figure 13). When each item is selected, the student may move to the next meal until ready to make a shopping list.

Shopping lists are made in any of three ways. They may be derived automatically from the menus the student selects; they may be created from scratch without particular regard to a menu; or they may be retrieved from disk. Typically, the first way is the most useful. The items on the shopping list are categorized according to the way they are presented in most grocery stores. For example, the vegetables are all grouped together.

This approach was developed with the cooperation of teachers from the John Archer School (Harford County, MD) and the Cedar Lane (Howard County, MD). These teachers agreed that the notion of combining a multimedia CAI program with a practical tool whose output could be used in a real grocery store was especially promising.

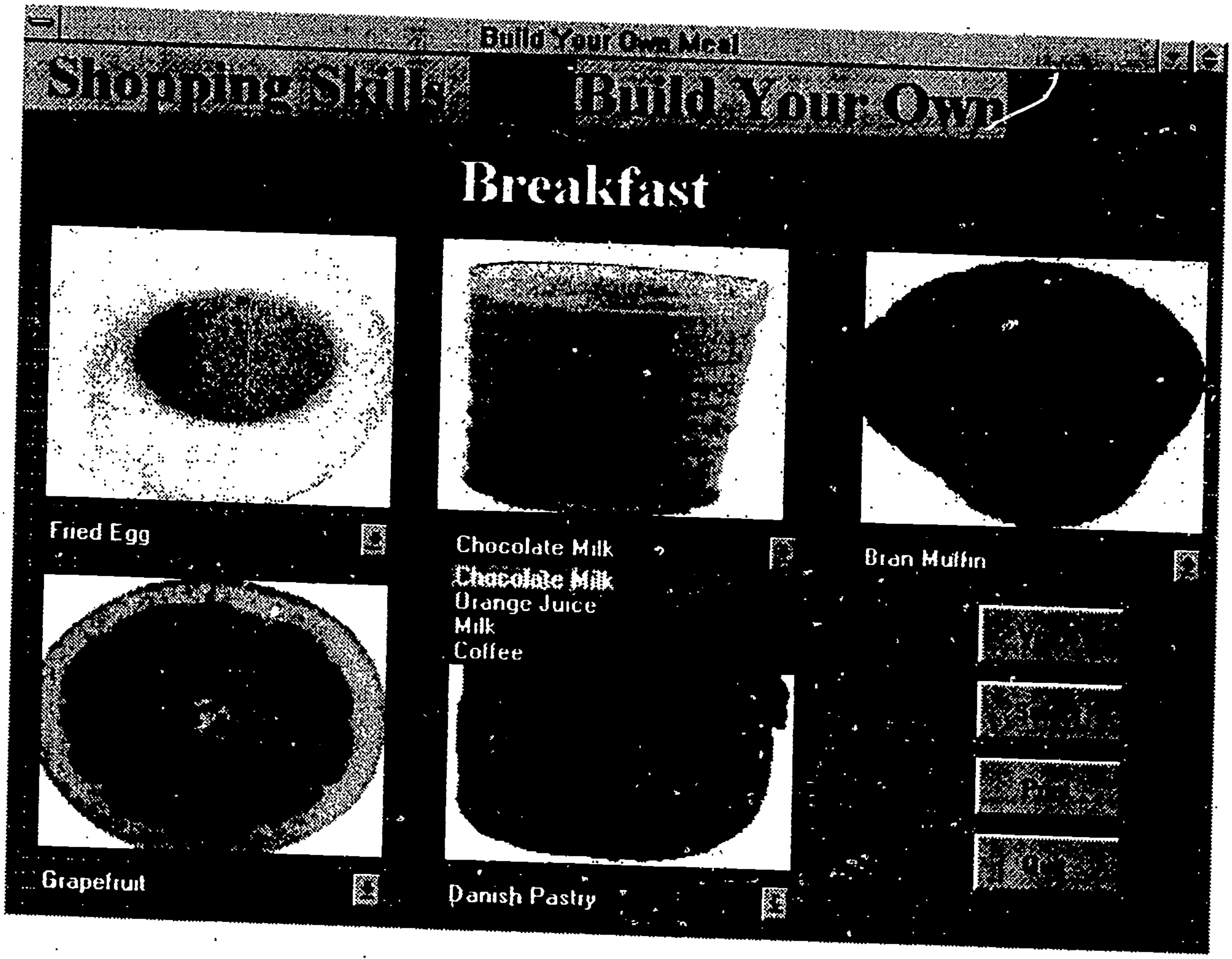


Figure 13. Selecting a menu with pictures, voice, and text.

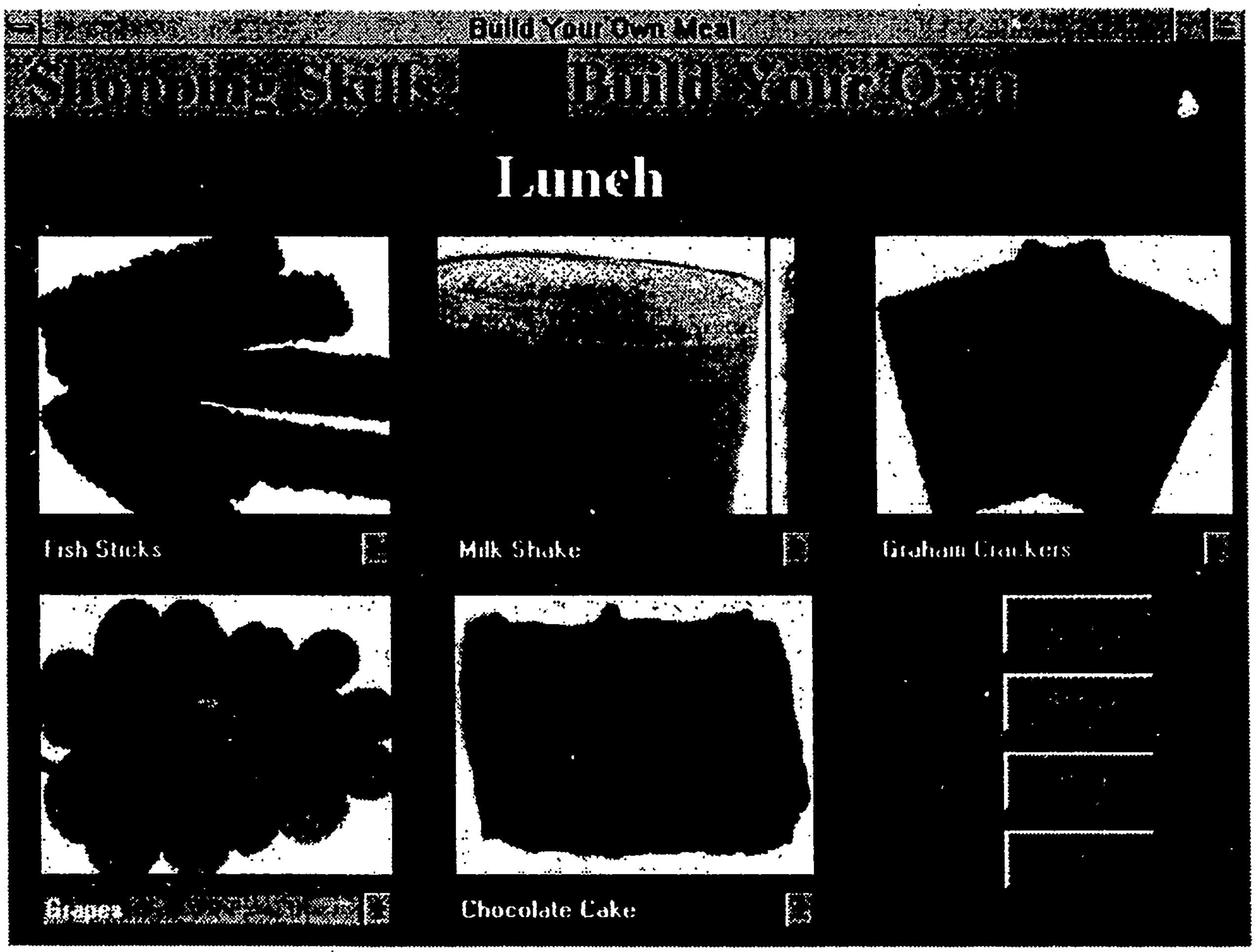


Figure 13. Selecting a menu with pictures, voice, and text.

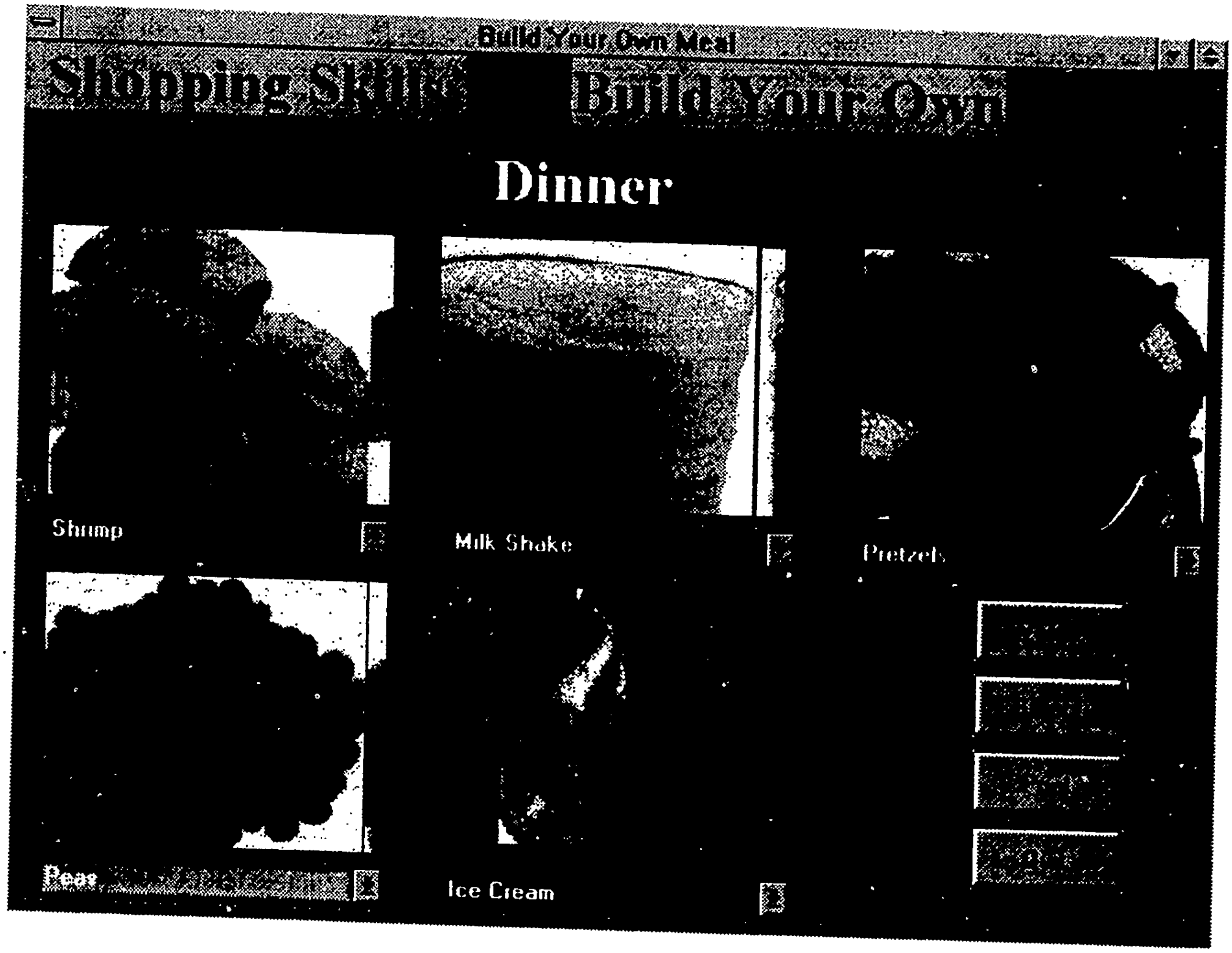


Figure 13. Selecting a menu with pictures, voice, and text.

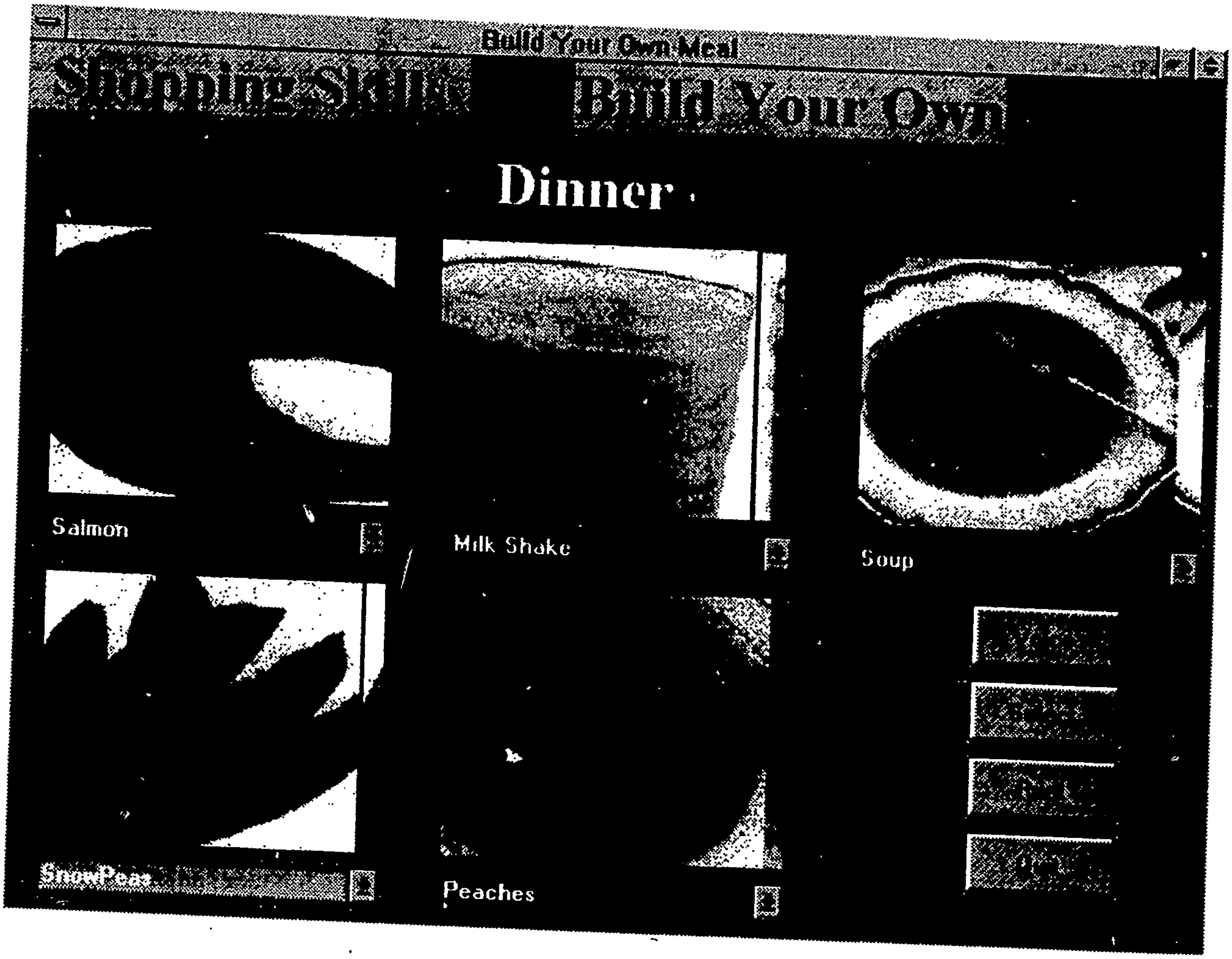
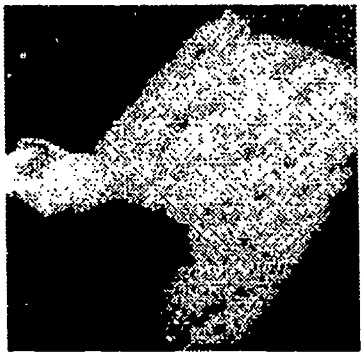
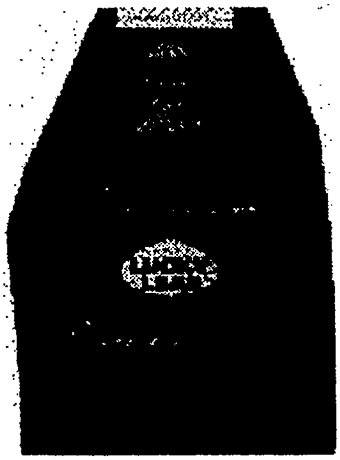
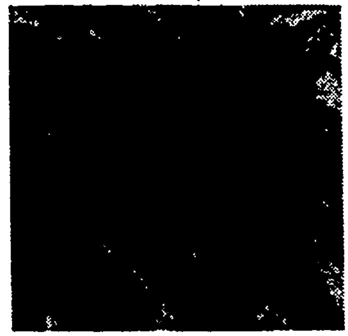
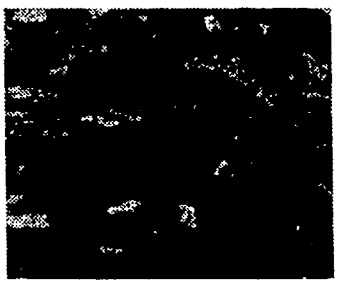


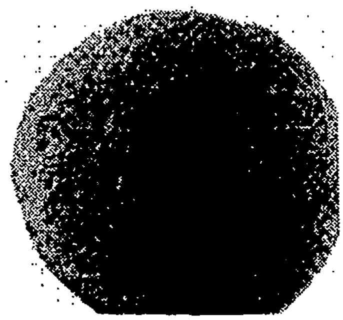
Figure 13. Selecting a menu with pictures, voice, and text.

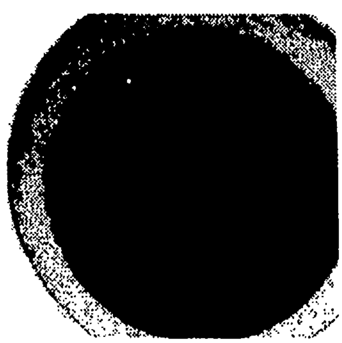


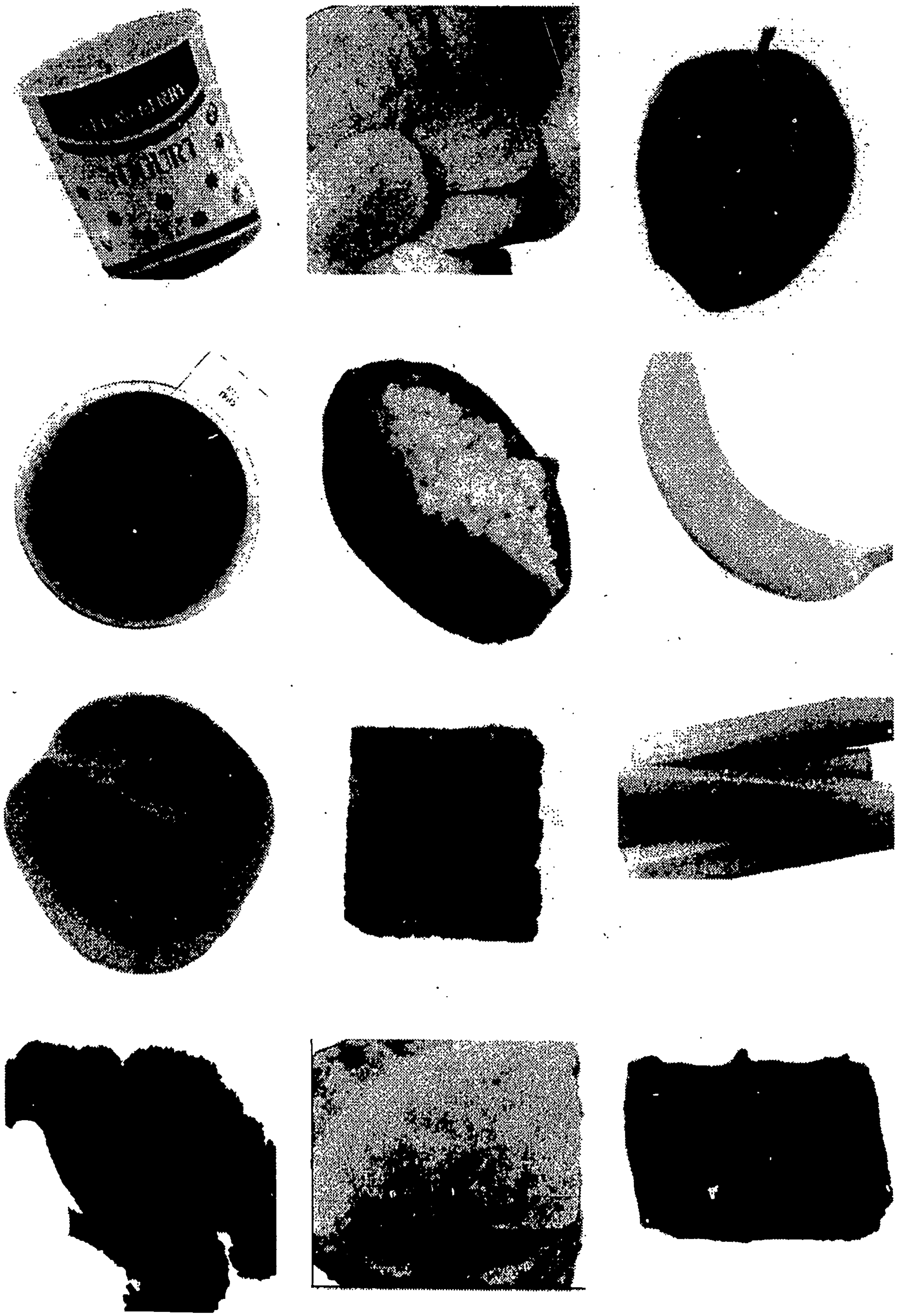












7. SOFTWARE METHODS

All the benchmarks were initially developed on APL's Multimedia Rapid Prototyping Tool and were evaluated by the team, and teachers, parents, students, and school administrators. Following the formative evaluation, they were adjusted while still in this flexible format before being committed to code.

The benchmarks for Social Studies and Critical Thinking Skills were developed for the Macintosh computer using the Hypercard System software. Extensive use was made of external routines in order to be able to access features that are not natively available to Hypercard, such as peripheral drivers, pull down menus, and 8-bit color.

Early in the program, it became evident that techniques were needed to optimize memory since multimedia is extremely memory intensive, particularly when digital video is used. The scheme followed was to store the multimedia data independently of the programs and call them when needed from external files. In this way, data modules could be reused, and new lesson modules required only a minimum amount of memory.

The Life Skills benchmark programs were programmed for MS-DOS compatible computers using Microsoft's Visual Basic. Additionally, external library routines were used to support features that Visual Basic does not natively support.

8. FUTURE RECOMMENDATIONS

The interdisciplinary team used the JHU-APL Multimedia Rapid Prototyping Tool (MRPT) to develop a series of prototype benchmark lessons for use with learning disabled and mild to moderately disabled students.

The MRPT, which was developed through internal APL funding to accelerate the development of multimedia software, proved to be an invaluable instrument in the field, allowing professionals with instructional expertise to visualize the multimedia benchmarks and contribute effectively to the evaluation and development of the program.

During the bi-weekly meetings held by the interdisciplinary team, meetings with educational practitioners in the field, and at professional conferences, such as the LDA International Conferences (Chicago, 1991; Atlanta, 1992), the MRPT was used to present the proposed benchmarks, and the ideas of the audience could be implemented in real time. This enabled the team to benefit from a very wide circle of experts, and these experts felt encouraged to see that their ideas were quickly and accurately implemented during the course of the meetings.

It also became apparent that the application of the MRPT could be broadened considerably to take advantage of new trends in multimedia education. Multimedia lends itself to projects that are tailored by a teacher for a particular class or, projects developed by teams of students for presentation to other students.

Relatively minor adaptation of the MRPT would produce the following benefits:

1. The development of a teacher presentation tool
2. The development of a tool that could be used by learning disabled students to create multimedia presentations for their peers

3. A curriculum development tool that would rapidly allow the development of multimedia lessons based on a wide variety of curricula

4. A tool for teacher training that would facilitate the rapid demonstration of multimedia effects and techniques.

It is recommended that the OSERS support the expansion of the MRPT to meet the above objectives.

APPENDIX I

Reprinted from

The Johns Hopkins APL Technical Digest

A. V. LOUIS BIGGIE, WILLIAM E. BUCHANAN, PAUL L. HAZAN, and ALEXANDER KOSSIAKOFF

A MULTIMEDIA RAPID PROTOTYPING TOOL FOR THE DEVELOPMENT OF COMPUTER-ASSISTED INSTRUCTION

A rapid prototyping tool has been designed to aid in the creation of computer-assisted instruction (CAI) software for children with learning disabilities and mental retardation. The tool, which was conceived and developed under the collaborative program between APL and the JHU Division of Education in the School of Continuing Studies, has enabled a multidisciplinary team of educators and computer engineers to visualize and test all features of proposed CAI programs on-line during regular design sessions held around a conference table. Computer program development time has thereby been significantly shortened, and significant gains have been made in the quality of educational products produced.

INTRODUCTION

A team of senior APL staff, JHU Division of Education faculty, and teachers of special education have collaborated since 1983 in the development of computer-assisted instruction (CAI) for students with learning problems. Although the initial products created by the Hopkins team have met with widespread approval of educators across the country, the team's first CAI programs took a very long time to define and implement. The main purpose behind developing a rapid prototyping tool, therefore, was to compress CAI software development time. Use of the tool, however, has also fundamentally improved the quality of the resulting educational products by affording educators increased opportunity to participate both in system design and in detailed decisions that are best made before time is committed to the writing of program code.

SPECIAL CAI NEEDS FOR SPECIAL EDUCATION

Software for CAI is, for the most part, produced and distributed by small commercial publishers. Although a broad range of high-quality CAI is available for general education students in preschool through grade 12, special educators have found that very few of the many thousands of available products address the curricular needs and individual strengths and weaknesses of their students. Since CAI for special education is expensive to develop and the market is small, the promise of the computer as a patient and versatile tutor of students with disabilities remains largely unfulfilled.

The features discussed in the following sections distinguish the requirements of CAI for students with serious learning problems from CAI that has proved successful in helping students who do not have perceptual, memory, neuromuscular, or intellectual deficits. Implementation of the required special features can transform an otherwise straightforward computer program into a complex and memory-intensive one. The final product, which is often a complicated program, needs to run in the small computers available to special education, typically 64-KB Apple IIs. Programs need to be fully optimized to fit in such a small configuration, a requirement that makes design modifications very difficult.

Individualization

A special education student is often characterized by a substantial discrepancy between ability and performance. Techniques that work for most students frequently are not effective in the special education classroom. What the exceptional child, and particularly the child with severe learning problems, needs are instructional approaches that make the most of strengths, interests, and preferred learning styles while remediating and/or minimizing the need for knowledge and skills that may be deficient.

The need for individualization has led the APL-JHU team to develop an authoring system that enables teachers to specifically tailor CAI to the developmental and chronological ages of their students and to special curricular needs as well (see the boxed insert entitled "Authoring Systems"). The Hopkins system is menu-driven for simplicity of use and designed so that a teacher without computer training can design a lesson that is complete and ready for student use in about one-half hour.

Feedback and Branching

In a typical CAI program, the student is asked to respond to questions, and the program either progresses automatically to the next question or determines the next question on the basis of the student's response or pattern of responses. The instructional approach for students in general education tends to be heuristic: the student is to find out which answers are correct and

MRPT PROGRAM DESCRIPTION AND OPERATION

The MRPT program, developed at APL and put into use in 1988, runs on a Macintosh computer in the HyperCard environment (see the boxed inserts entitled "HyperCard" and "MRPT Hardware Considerations"). The code is written in Hypertalk, the high-level programming language that comes with HyperCard. Additional routines have been appended to the HyperCard shell to support peripherals (Fig. 1).

HyperCard enables nonprogrammers to create a wide range of application programs. Routines, functions, and graphics are invoked by an intuitive system of pull-down menus, icons, and interaction with the mouse. HyperCard also has all the features of a conventional database. A central feature used by the MRPT is HyperCard's ability to store routines in the form of "buttons," which, if accessed with the mouse, execute a software routine without the user ever having to see or even be aware of the code that is associated with it. Graphics, voice, music, and access to videodiscs are easily incorporated into HyperCard-based designs.

The design of the MRPT involved the merging of the features native to HyperCard with routines that were identified as necessary for designing CAI for special education. The code associated with the program functions had to be transparent to the user and easily accessible. Therefore, a menu-driven system based on a simulated control panel was designed.

To allow the designer to focus on the design of a system application rather than on the details of its implementation, software routines have been incorporated to merge several steps into one or two mouse clicks. This feature makes implementation of software functions considerably faster than in the raw HyperCard environment. The MRPT also provides access to all the routines built into HyperCard. For example, a user can access a bitmapped painting program, which includes all the tools usually used by computer graphic artists.

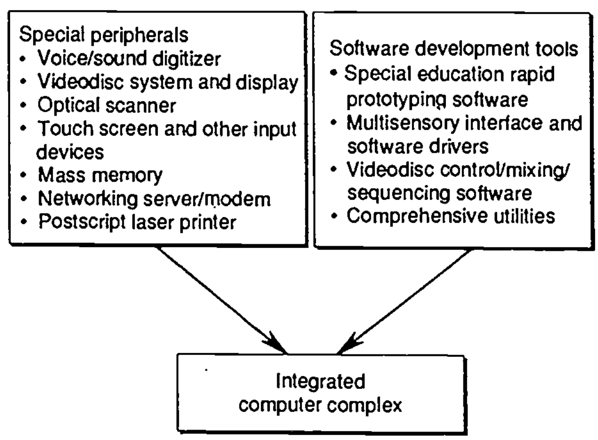
The MRPT enables the Hopkins CAI design team to create realistic models of student lessons and authoring protocols without writing code. Educators and computer system designers are thus able to focus on their respective fields of expertise. Routines can be invoked in the model instantly so that a wide range of ideas and potential system configurations can be explored and evaluated. Misunderstandings among members of the design team are minimized because the system permits the visualization of each software module and of its role in the final product. Design alternatives are presented in a realistic environment. Because the model is operational, the tests to verify usability of the system begin in the design session rather than after the system has been programmed and placed in the field. Such real-time rapid prototyping is more likely to yield first-pass success and thereby avoid the time-consuming process of redesigning and reprogramming software.

The tool facilitates the design and scrutiny of the layout and organization of text, graphics, and multimedia material; the use of the keyboard and other input

MRPT HARDWARE CONSIDERATIONS

The MRPT runs on a Macintosh computer with a minimum of 2 MB of random-access memory (RAM) and a hard disk drive. An optical scanner is used to read pictures into student lesson programs, and Macrecorder, an inexpensive speech digitizer, provides a means of incorporating speech. During meetings of the multidisciplinary development team, a liquid-crystal display projection device is used with a high-quality overhead projector to display the Macintosh screen. The programmer spends the meeting at the keyboard continuously orchestrating and implementing design ideas as they arise.

After a substantial part of a design (e.g., a lesson or authoring module) is approved by the team, the prototype MRPT-based modules are coded on an Apple IIgs, which is part of the development laboratory. The resulting authoring system programs used by teachers are designed to run on Apple IIe/IIgs computers with 128 KB of RAM, two disk drives, and a printer. Student lessons generated by authoring programs are configured to run also on all Apple II machines, including the older Apple II Plus computers with only 64 KB of RAM and one disk drive.



Environment for multimedia rapid prototyping.

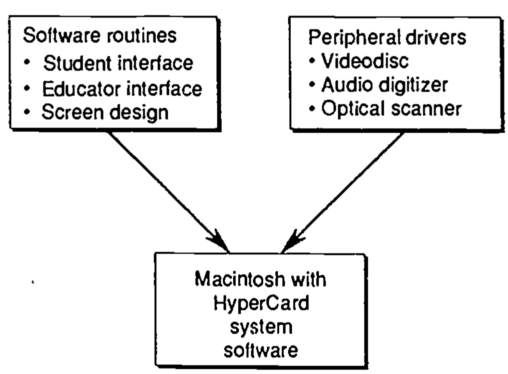


Figure 1. Multimedia rapid prototyping software.

devices; branching control; feedback; and record keeping. It allows several candidate display models to be conceived, created, displayed, and assessed at a single design session. The result is a more effective design implemented in a shorter time.

The MRPT software display, illustrated in Figure 2, contains two major components: a control panel to manipulate the screen design and simulation, and a screen on which the simulated program is run. The control panel contains several buttons that activate a library of software routines, each of which performs a specific function involved in designing authoring or lesson screens. A function is turned on by using a mouse to move a pointer to the appropriate button.

Functions

Figure 3 illustrates the use of control buttons to add a new menu function to a screen, namely, an additional command function. This feature uses the control button in the lower section of the control panel called "New function," which creates new commands in the prototype (Fig. 3A). When selected, this button displays a pop-up menu that offers the user a choice of functions (Fig. 3B). The selected function is highlighted, and the feature is placed in the program in the form of a command key. The newly created key appears in the screen area, and the software associated with it is automatically and transparently transported (Fig. 3C). It can now be accessed, activated, and tested with the mouse. Its position, appearance, and parameters can be altered by using point-and-click dialog boxes.

A wide range of functions is included in the MRPT software, and new ones will continue to be added to respond to existing and anticipated needs.

Cards

In the HyperCard environment, each screen of information is organized in a relocatable module called a "card." This feature enables program modules to be easily referenced and recalled. Control commands can quickly define links between one card and another. This ability allows designers to simulate a working program easily and quickly by creating new cards and linking them. For example, if the design team suggests that a feature be included to create a certain effect, a card is created to show the appearance of the screen before the feature is activated; a second card shows the screen after the feature is activated. Finally, a screen command in the form of a button links the first card to the second. The feature is now operational in the prototype and can be activated with the button, but no programming has been required to produce the effect.

Cards can also be used to create animation. For example, graphics can be placed on a series of cards, which are then displayed in rapid sequence. This feature is also used to demonstrate the movement of textual material from one part of the screen to another.

Cards are frequently employed so that designers can easily view the general flow of a program, and provision is made so that the sequence can be altered. The sequence of data presentation is frequently a critical element in educational software, and this easy means of evaluating alternative sequences has had very positive effects on determining the most pedagogically sound version.

Fields

Typically, a student lesson screen consists of several areas or fields devoted to different uses: an instruction field, a student question field, a student answer field, and a feedback field. A new field can be created by clicking on the "New field" button. The field can be placed anywhere on the screen, and pop-up menus and dialog boxes allow the program designer to specify its type. As far as the program designer is concerned, the MRPT makes the manipulation of the field type as easy as mak-

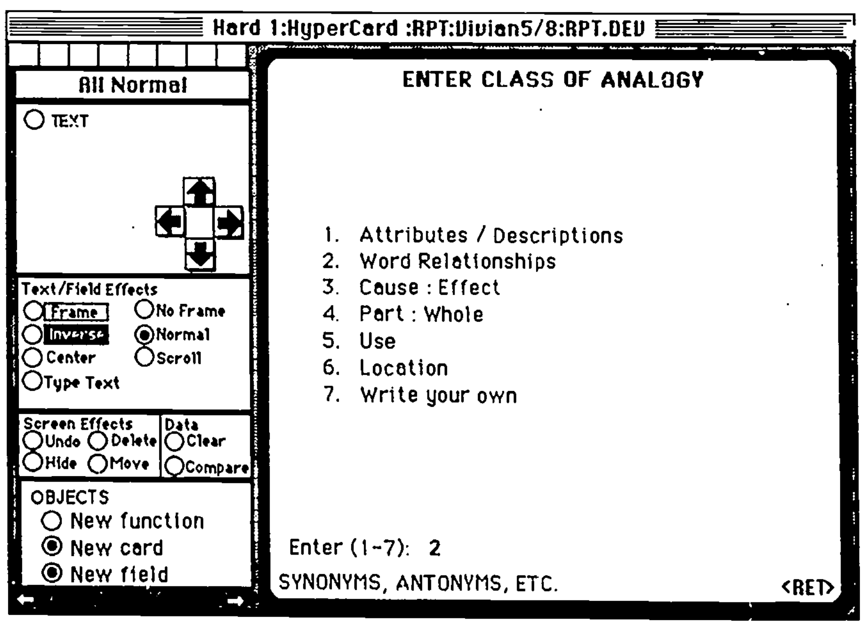


Figure 2. Sample MRPT screen. The control panel (left) controls the rapid prototype program. The buttons (labeled circles) activate a library of software routines, each of which performs a specific function involved in designing authoring or lesson screens. A function is turned on by using a mouse to move a pointer to the appropriate button. The prototype program is run in the screen area (right).

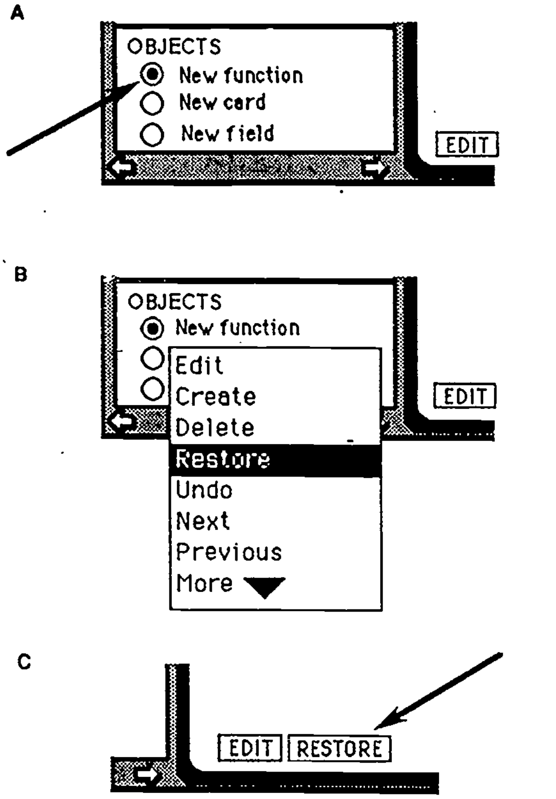


Figure 3. Creating a "Restore" function with the APL-JHU MRPT. A. The user activates the "New function" option by pointing and clicking. B. A pop-up menu appears to allow the user to choose the new function. C. The system model now has a fully operational "Restore" function. The user can now use the mouse to position it.

ing selections from menus. The approach is identical to the selection of the function of a button (see Fig. 3). Changing the field type automatically alters the code associated with it so that it plays a different role in the program. For example, an instruction field is usually noninteractive because its purpose is to provide information to the student. Thus, the code embedded in the instruction field prevents the student from typing information in that area of the screen. When a student response is needed, an answer field can be created so that the student can input data.

Program designers may also specify whether or not a field is visible. Making a field temporarily invisible permits the prototype program to be designed so that information is progressively disclosed. The order and length of time that a field is either visible or invisible can critically alter the style of teaching. Also, under certain circumstances, the visibility of a field can be placed under student control, thereby providing the ability to create "Help" screens that the student can access at will. Other fields may be permanently invisible to the student and serve only as data sources. Provision is made so that these fields can be fed from other data sources, such as word processors.

Additionally, the appearance of a field can be quickly altered by the MRPT. This feature allows the character size, font, justification, and margins within the field to be altered. A whole field can be changed from uppercase to lowercase, for example, simply by clicking the mouse twice.

Multimedia Interface

Integration of computer and video technology holds great promise for the creation of more interesting, meaningful, and effective educational materials than in the past. Programs can also be made to switch from medium to medium adaptively. For example, text can be used when it is the most suitable medium, but software can switch the program to voice, graphics, and video as needed.

Routines embedded in the MRPT allow program designers to access multimedia peripherals and incorporate their use into the system model. Media branching also creates exciting possibilities for the educator concerned with the assessment of learning disabilities. For example, a traditional reading test often does not clearly indicate whether a student's problem is linked to a reading disability or to difficulty with the subject matter being presented. A multimedia program can help solve this problem by reporting and comparing a student's performance on the same or similar materials presented in a variety of media.

Videodisc Players

A videodisc player can play back film and video material just as a videocassette recorder can, but with many extra features that have interesting implications for education. Videodisc players can be controlled by computers on a frame-by-frame basis. An educational program can be designed in which students might see a film clip and then answer questions about what they saw. The film can then branch to another sequence that might explain an error made in the answer or go to new material, depending on the student's response.

With the MRPT, this type of educational or assessment program can be prototyped, viewed, and evaluated instantly. The videodisc player is controlled by an interface on the computer screen that looks very much like a remote control unit for a home videocassette recorder. In this way, control functions can be created that switch the videodisc player on or off, replay a segment, or move to a new scene in a film possibly containing a hint or some feedback.

Other features of the videodisc player include the provision of two separate audio tracks. This feature has been used in the past to create bilingual discs but could also be used very advantageously by special educators. For example, by changing tracks the program can switch the program from an expository presentation to questions, followed by feedback to the student based on the correctness of answers.

When integrated with a computer system, videodisc technology allows the user to annotate pictures by overlaying text or graphics. The MRPT software makes this overlay technique simple. A button activates a dialog box, and the user enters text into a field automatically created for this purpose. The data are then sent to the videodisc player via the serial port on the Macintosh computer. Videodiscs can also be created to contain up to 54,000 still frames, thereby providing an enormous range of pictures that can support or expand explanations made through other media and live video action.

Digitized Speech

Educational programs, particularly those designed for students with severe learning problems, can be greatly enhanced by the use of natural-sounding digitized voice. An interface to a speech digitizer is built into the rapid prototyping tool. During a design session, voice segments can be recorded, incorporated, and evaluated. A voice segment can be moved from one part of the program to another to decide at what stage it would be most effective.

Optical Scanner

The MRPT can incorporate bit-mapped graphics into system prototypes. These can be transferred from graphics programs that operate on the Macintosh. Also, by using a scanner, it is possible to incorporate any printed picture into prototype educational software.

Benefits

The MRPT is being used to design all of the component programs in a family of CAI software to help learning-disabled children improve their reading skills. This software system includes two modules in comprehension skills, one in word analysis (analogies), one in textual analysis, and one in sequencing. All of these programs can be authored; thus, a user interface is required for both the lesson designers and the students. In the future, the system will include extensive database capabilities to keep track of lessons and student performance.

The most tangible benefits of the MRPT are the greater involvement and contributions it encourages of members of the interdisciplinary team. In the past, team members were reluctant to submit ideas that had not been thoroughly considered before meetings because they realized the trouble and cost involved in translating ideas into computer code. Spontaneous ideas, however, often develop into valuable features. The prototyping tool encourages this kind of creativity. The tool also helps new or visiting members of the team become knowledgeable about issues surrounding the program in a very short time. Familiarity with the technical design and context contributes to their critique in vital subject matter and content areas. Perhaps the most dangerous pitfall of interdisciplinary teaming is when an educator spends time, effort, and energy working not as a professional educator, but as an amateur software designer. The use of online rapid prototyping helps avoid that trap.

Not only has the level of creativity increased significantly with the use of the MRPT, but the potential to respond to that creativity has also increased. Complicated ideas have been demonstrated almost instantly by using the building blocks provided by the MRPT.

Because it has become easier to be involved in the design of the system model, the team has been able to use the advice of a broad community of experts. As a result, the latest programs of the APL-JHU team were designed with advice from specialists in a wide range of disciplines: learning disabilities, reading, mental retardation, hearing impairments, physical handicaps, emotional disturbances, and educational research. Input from many areas makes the resulting software attractive to more end users.

Finally, the benefit of the tool extends to the applicability of its techniques to the design of other kinds of software. Because MRPT has been used to design a very complete CAI software system, it can handle a wide variety of software types. For example, in the record-keeping component of the program, the tool is being used to design charts and graphs to assist in the analysis of student performance. The techniques used in this phase are more typical of the design of a business graphics package than of traditional CAI. Similarly, the design of the library system has much in common with database management system design.

CONCLUSIONS

The benefits of the MRPT are believed to have greatly enhanced the value of the CAI that has been developed with its use. In addition, the MRPT is expected to be even more significant as the work moves into the stage of merging video and voice technologies into the authoring systems for instruction and assessment.

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In recognition of his work on national defense during World War II and at APL, Dr. Kossiakoff was awarded the Presidential Certificate of Merit, the Navy's Distinguished Public Service Award, and the Department of Defense Medal for Distinguished Public Service. He is a Fellow of the American Institute of Chemists and a member of the American Association for the Advancement of Science, the Cosmos Club, and the Governor's Scientific Advisory Council.