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ABSTRACT

Systems incorporating two advanced technologies, hypermedia systems and intelligent tutors, are examined with respect to their potential impact on science education. The conceptual framework underlying these systems is discussed first. Applications of systems are then presented with examples of each in operation within the context of science education. The use of hypermedia within a problem solving environment in which students analyze case studies of real patients is discussed using as an example a system to teach orthopedics. The potential for applying hypermedia to the assessment of learning is described with students using software to balance chemistry equations (Hyperequations). Applications of level-3 interactive video presents counterintuitive events to stimulate students to seek explanations through problem-based learning. Finally the design of an intelligent tutoring system to teach problem solving skills important to transfusion medicine is described. Design issues related to each system are reviewed and specific questions raised regarding the effective use of such systems. In some cases, preliminary studies have been conducted related to these questions and some potential future directions are presented. As these technologies develop and as other technologies emerge, their use in education suggests greater flexibility in both instruction and assessment of learning. (Author)

Advanced Technologies as Educational Tools in Science:

Concepts, Applications, and Issues

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Systems incorporating two advanced technologies, hypermedia systems and intelligent tutors, are examined with respect to their potential impact on science education. The conceptual framework underlying these systems is discussed first. Applications of systems are then presented with examples of each in operation within the context of science education. The use of hypermedia within a problem solving environment in which students analyze case studies of real patients is discussed using as an example a system to teach orthopedics. The potential for applying hypermedia to the assessment of learning is described with students using software to balance chemistry equations (Hyperequations). Applications of level-3 interactive video presents counterintuitive events to stimulate students to seek explanations through problem-based learning. Finally the design of an intelligent tutoring system to teach problem solving skills important to transfusion medicine is described. Design issues related to each system are reviewed and specific questions raised regarding the effective use of such systems. In some cases, preliminary studies have been conducted related to these questions and some potential future directions are presented. As these technologies develop and as other technologies emerge, their use in education suggests greater flexibility in both instruction and assessment of learning.

Introduction

Advances in conceptual approaches, as well as in software and hardware technologies, offer powerful methods for enhancing the use of computers as educational tools in science. The use of hypermedia to provide non-linear access to text, graphics, sound, and video is one such important advance (Conklin, 1987; Halasz, 1988; Glusko, 1989; Norman, 1988). The incorporation of "intelligence" in a tutoring system is another advance (Anderson, Boyle, & Reiser, 1985; Clancey, 1984; Kearsley, 1987; Sleeman & Brown, 1982; Wenger, 1987; Woolf & McDonald, 1985). While there have been a variety of efforts to make use of these advances, there are many important, unanswered questions that need to be dealt with in order to assess the effectiveness of these technologies and to guide the design of effective tutoring environments.

This paper describes the concepts, applications, and issues associated with two rather different technologies, the use of hypermedia [including level-3 interactive video (IVD)] and intelligent tutoring systems, in science education. One approach [as demonstrated by the "Gait Analysis Instruction Tool (GAIT)," "Hyperequation," and "Hyperscience 456"] involves using hypermedia techniques (including IVD) to provide instruction, to assess the process of problem solving, and to provide a context for problem solving respectively. A second approach (as illustrated by the "Transfusion Medicine Tutor" later in this paper) provides a problem-based learning environment (Barrows, 1988) in which intelligent tutoring capabilities are incorporated to provide feedback and guidance to the students.

Hypermedia and Level-3 Interactive Video

In 1945 President Roosevelt's science advisor, Vannevar Bush, wrote in the *Atlantic*, describing a (hypothetical) tool that would link related pieces of information. Such a tool could be used to manage information in new and innovative ways, by forming omni-dimensional associations or links (Tsai, 1988; Marsh & Kumar, 1992). Bush has been credited with being the pioneer of this idea of "using a machine to store connections between pieces of information" (Smith, 1988, p. 33).

Hypermedia is based on this idea of linking related information. It is an interesting extension in that very different types of information and information displays are linked, ranging from text and simple graphics to video. According to Halasz (1988), hypermedia represents "a style of building systems for information representation and management around a network of multimedia nodes connected together by typed links" (p. 836). The design of a hypermedia environment is supported by software such as the HyperCard™ and SuperCard™, which allow the creation of networks of interconnected electronic cards, or screens, to represent a collection of related ideas in the form of visual text and graphics, and to facilitate the organization, storage, and retrieval of information (Halasz, Moran, & Trigg, 1987; Halasz, 1988). In such environments, each screen is thought of as a "notecard" (node) and the associated concepts are linked via electronic "buttons" (links) (Dede, 1987; Halasz, 1988).

In addition to linking each card with additional printed information, links can also be made to nodes containing "information" such as audio or video (Mulhauser, 1992; Ambron & Hooper, 1988; Aambo & Hovig, 1988). For example, in level-3 interactive video systems, software such as HyperCard™ in an external microcomputer is used to control the learner-video interaction allowing "students to manipulate audiovisual materials stored on the videodisc in numerous ways" (Litchfield & Dempsey, 1992, p. 40). A reasonable amount of educational applications of hypermedia are in the level-3 interactive domain.

Proponents of hypermedia suggest that it can be used effectively to support learning for a number of reasons, two of the more important are:

- The use of audio and video displays make it possible to provide richer environments in which information is provided in real-world contexts (Kumar, 1991a; Hofwolt, Kumar, & Altman, 1991; Litchfield & Dempsey, 1992). Such contexts arguably serve to motivate students, as well as enhance recall of important points.
- The use of links to easily access related knowledge encourages students to explore these relationships. The assumption is that "the more links that can be formed between existing knowledge and new knowledge, the better the information will be comprehended and the easier learning will be" (Jonassen, 1988, p. 13).

Intelligent Tutoring Systems

Over the last two decades, there has been a great deal of interest in the development of intelligent tutoring systems (Anderson, Boyle, & Reiser, 1985; Clancey, 1984; Sleeman & Brown, 1982; Wenger, 1987). The assumption behind this research has been that, with greater "intelligence," computer systems can provide more adaptive and therefore more effective tutoring. According to Woolf (1987) the goals of intelligent tutoring systems include representing knowledge, monitoring student learning, tailoring instruction to the individual learning needs of students and providing a macro context for learning.

The goal of this research has been to build highly adaptive teaching machines. These computer systems not only have knowledge of how experts perform problem solving, but also have other knowledge relevant to teaching. Included is knowledge of students' common "naive conceptions" and errors. Also included is knowledge about how and when to apply various teaching strategies. Some intelligent tutoring systems (ITS) design concepts are described below.

ITSs typically have three major components: the expert system, the student model, and the tutor. The knowledge provided by these components is used in a variety of ways to support interactive teaching.

The expert system provides a representation of the knowledge and problem solving processes consistent with correct expert performance. This knowledge is used for two purposes: to help detect errors on the part of a student and to provide supporting explanations and teaching about correct performance. One function of this expert knowledge, then, is to help the system develop its "student model" for a given student (a representation of what the computer thinks the student does and does not know). Students may differ from the expert model in that they may be missing some of the declarative or procedural knowledge important for expert performance or they may have incorrect or naive declarative or procedural knowledge. Another function of the expert module is to support the tutoring module in providing explanations and guidance to the student.

The student model for a given user (student) is developed by observing the correct and erroneous performances of the student. To make inferences from observed behaviors, the computer makes use not only of its expert knowledge (to answer the question: does this student's performance differ from that of an expert?), but, also, of a collection of knowledge about stereotypical incomplete or naive conceptions that students often have. Thus, like an expert human tutor, the ITS knows what types of naive conceptions students typically have and can infer their existence from the errors made by a student.

Tutoring involves more than determining a student's naive conceptions and areas of ignorance. Thus, the "tutor" must make use of the knowledge provided by the "expert system" and also of the insights provided by its "student model." The "tutor" must implicitly or explicitly consider alternative teaching methods based on the current context and its interactions with the student up to that point. In discussing the design of an ITS, Collins, Warnock, and Passafiume (1975) suggest a number of teaching principles, such as:

- Asking the student to parrot what she/he has just read is "a mode of recall that leads to little or no long-term retention" (p. 70);
- Asking review questions covering previously taught material when it comes up in another context is an effective way to reinforce learning;
- Asking a question about the student's wrong answer and not simply teaching the student the right answer when he/she makes a mistake helps "the student remember the distinction" (p. 73).

Similarly, Woolf (1987) suggests selecting learning tasks which "illustrate similarities among related phenomena" (p. 232) and which provide "heuristic knowledge" (p. 239). Thus, the literature on ITS research provides a great deal of insight into the design of educational systems, both at an architectural level and in terms of principles for effective teaching.

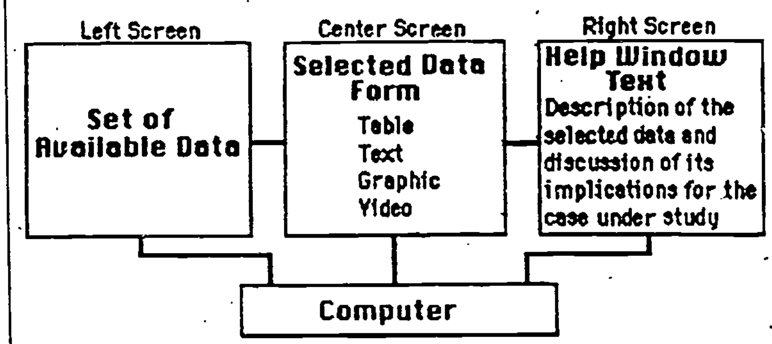

Figure 1. Schematic diagram of GAIT display

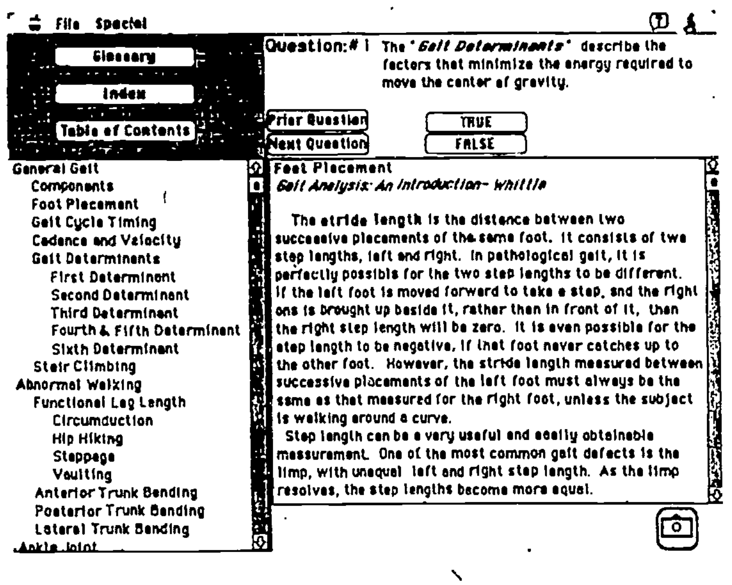

Figure 2. Sample GAIT on-line "book"

Sample Systems and Research Issues

In order to highlight important research questions associated with the use of hypermedia (including level-3 interactive video) and ITS technologies, specific applications are reviewed below.

Hypermedia Systems

The Gait Analysis Instructional Tool (GAIT) is an example of a hypermedia tutoring system designed to teach aspects of orthopedics with case studies of real patients. This system provides a problem solving environment in which students learn while answering questions and analyzing complete patient cases (Barrows, 1988; Boring & Nutter, 1984; Burnett, Mahoney, Chidley, & Pierson, 1986; Cardiff, 1986; Irby, 1986; Henry, 1985).

GAIT has two components. The first, written in SuperCard (authorware similar to Hypercard™) asks students questions and provides access to text and video to help them learn. The second, written in C, provides access to complete patient cases. GAIT runs on a Macintosh II using three, color monitors. When solving complete patient cases, students can request any of the data normally available to a physician by using the cursor to click on the corresponding button (see Figure 1). The set of available data is always displayed on the left screen.

When a particular piece of data is selected for viewing, it is displayed on the center screen (see Figure 1). The data displayed may be a table (text), graphics or video. The student can use the available data to make inferences (ruling out certain hypothesized dysfunctions). If the student has problems doing so, he/she can click on any data display with the mouse and a help window appears. This help window includes written text describing this datum in general, as well as providing a discussion of its implications for the current case. Such full patient cases are suitable for more advanced students.

For novices, GAIT provides access to an on-line "book" (complete with table of contents, index, and glossary) and a set of specific questions that students should be able to answer. For instance, by clicking on an entry in the glossary, a definition appears in a "pop-up window." Specific sections identified in the table of contents also have associated graphics and video, which can be displayed upon accessing that section of the "book." Figure 2 shows this component of the system.

A second way to use this component of GAIT is to try to answer the study questions. When the student answers a question, GAIT provides feedback and tutoring. This tutoring provides access to:

- A context-sensitive table of contents that indicates the relevant sections of the on-line "book" to read;
- A video display in which an expert discusses the answer to that question (audio feedback) while appropriate video (of a patient, for example) and graphics are displayed.

In general terms, GAIT has three interesting features. First, information is displayed in several different media (text, graphics, speech, and video). Second, this information is linked as appropriate to provide easy traversal among related pieces of information. Third, there are different conceptual approaches to accessing the information (browsing through an on-line "book" versus asking for tutoring in response to a particular problem). These three features serve to illustrate the capabilities provided by hypermedia.

An interesting, yet challenging, application of hypermedia is in the design of assessment or evaluation tools. According to Shavelson, Baxter, Pine, Yure, Goldman, and Smith (1990), standardized paper-pencil tests are not sufficient to measure the process skills involved in hands-on science instruction.

Simulations of hands-on problem solving while using computers to teach often serve to develop higher order cognitive skills (Gilman & Brantley, 1988). But, such computer based learning often lacks assessment systems that are "computer gradable" (Moore, 1989).

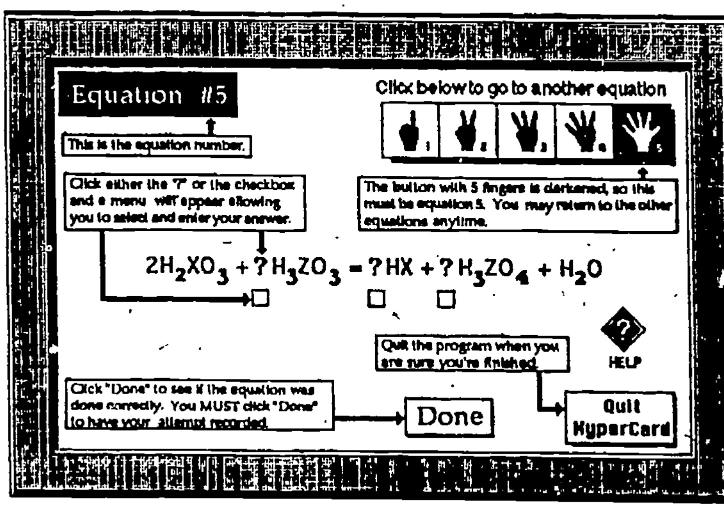

Figure 3. Sample Hyperequation
(©1991 David D. Kumar)

One potential solution to these problems is the use of hypermedia systems that are capable of assessing the process of learning. Under the New Technologies Focus Area at the National Center for Science Teaching and Learning, research on alternative assessment systems using HyperCard™ (on a Macintosh II computer) is in progress. Using custom developed assessment software called "Hyperequation" (Kumar, 1991b), the performance of high school students in the task of solving stoichiometric chemical equations has been studied.

The term Hyperequation refers to an approach to writing and balancing chemistry equations using HyperCard™ in Macintosh computers. Some of the features of Hyperequation include easy operation using the computer mouse, immediate feedback, and the ability to register information pertaining to the process of problem solving such as the order of responses made by the students. In addition, Hyperequation also provides an item by item score for each student. In effect, Hyperequation not only substitutes for a paper-pencil test involving balancing chemical equations, but also provides a non-linear visual assessment environment (flexibility to go in any direction) on a computer screen. A sample Hyperequation is shown in Figure 3. See Figure 4 for a sample Hyperequation record storage.

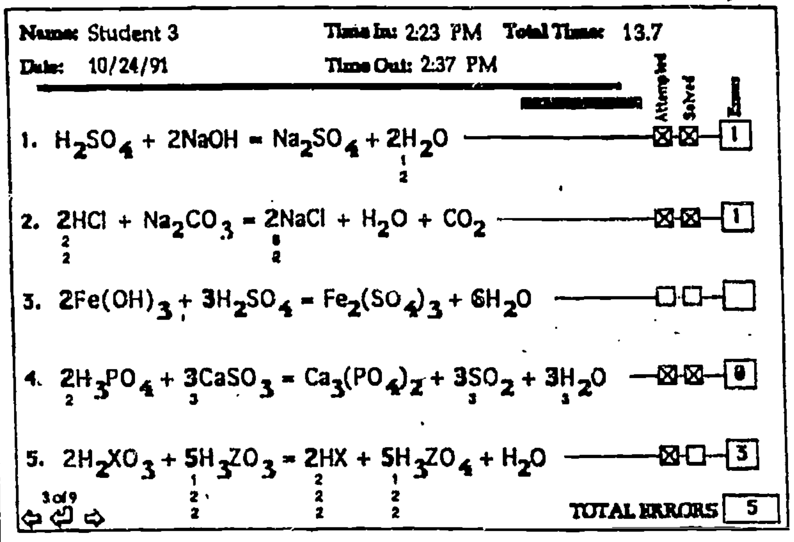

Figure 4. A sample display of Hyperquation report
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Other advantages of Hyperequation include the following. Hyperequation is easy to write using HyperCard™. It can be linked to databases of chemical indexes, electronic configurations, chemical bonding, and HyperCard™ periodic tables in case the student wants a quick review of some background information. As HyperCard™ software, Hyperequation can be linked to selected video segments from professionally produced chemistry videos (e.g., the "Periodic Table Videodisc" of Project Seraphim) through electronic buttons and transformed into a tool for instruction in chemistry. Developments are underway to refine Hyperequation to incorporate capabilities that would recognize and react to the problem solving strategies employed by students.

Another application of hypermedia in assessment is evident in an on-going project reported by Martinez (1991) where an "IBM-compatible computer interface delivery" platform has been used for the delivery of figural response assessment items in cell and molecular biology. Martinez (1991) has used a "figural response item format" in a computer environment which enables the measurement of knowledge that is difficult to express in verbal or numerical forms. Using a set of computer screen tools activated by buttons (e.g., "move object," "rotate," "draw line"), chromosomes and molecular groups are moved on the screen by students to respond to various questions. One such question reads as follows: "Given the D-glucose below, construct its L-glucose stereo-isomer using the template shown." Martinez (1991) concluded that figural response assessment strategies, in combination with existing assessment methods, "broaden the kinds of thinking called for by tests." Similar work in physics at the University of California-Santa Barbara in collaboration with the California Institute of Technology has been reported by Shavelson, et al. (1990).

Hypermedia Design Issues

One of the concerns in designing hypermedia systems is navigation (Jonassen, 1988; Marchionini, 1988; Smith, 1988), "knowing where one is, where one wants to go, and how to get there from here," (Parunak, 1989, p. 47). Because of the passive nature of the links provided by such systems, the user has to choose to pursue some path. This concern over whether the student will choose to pursue the appropri-

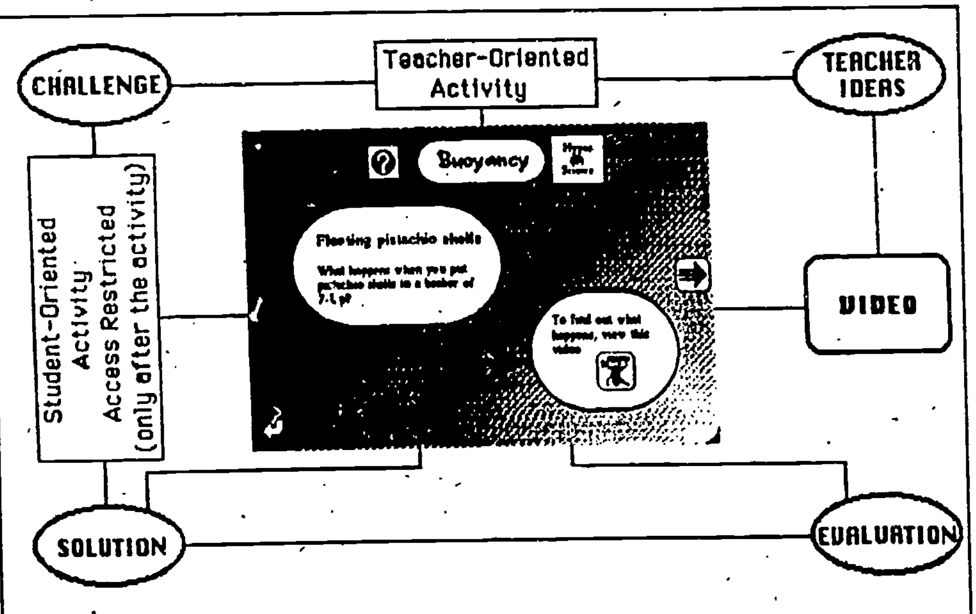

Figure 5. Schematic diagram of Hyperscience (Hyperscience was first presented at the 1991 NSTA Convention in Houston, Texas)

ate path to learn important material raises a number of issues. First, the student must recognize that he/she needs help in learning something and decide that it is worthwhile to do so. Second he/she must decide where to go to learn this material.

Thus, giving the user control is a double-edged sword. It may reduce tedium and give the student a sense of control. It does not, however, ensure that important material will be viewed, let alone learned, and "it is not clear how hypermedia can best support learning and instruction" (Jonassen, 1992, p. 4). A great deal of research remains to be done on how to structure hypermedia (Gordon & Gill, in press) and how to influence students to make appropriate use of the available links.

Level-3 Interactive Video Systems

"Hyperscience 456" (Hofwolt, Kumar, & Altman, 1991) is an example of an application of level-3 interactive video technology. Hyperscience presents counterintuitive events or discrepant events (using a video disk) in order to stimulate curiosity, wonderment, critical thinking, and a need for students to seek explanations for the observed phenomena. The video disk interacts with a HyperCard™ stack in a Mac II computer via a Pioneer 4200 videoplayer, with images displayed on a Sony color television.

Instead of looking at still photographs, in Hyperscience the learner gets a first hand view of the counterintuitive event in action on a color TV monitor. This capability enriches the context of the learner-machine interaction. The topics include Air and Pressure, Buoyancy, Characteristics of Matter, Heat, Light, Magnetism, Mechanics, Sound, and Earth Science. An example of a Hyperscience 456 stack arrangement is shown in Figure 5.

Hyperscience is designed to support the teacher in introducing and reinforcing specific science concepts and in teaching problem-solving. It does so in several ways. First, a catalog of carefully selected problems has been assembled for use by the teacher. Second, appropriate teaching strategies such as discovery learning and verification experiments using the laboratory are suggested to the teacher. Third, videos of the counterintuitive events make them "real" and serve to stimulate thought and discussions by the students. The normal mode of use is for the teacher to lead a class discussion using Hyperscience to display video segments or for the teacher to circulate among groups of students (each at a computer workstation) and to engage them in group discussions. Outcome studies are in progress.

This use of the computer to facilitate instruction and to stimulate discussions is further evident in the "Teacher Education Project" (Goldman & Barron, 1990). In the Teacher Education Project, an interactive video environment is employed to present videos of contrasting instructional strategies and to initiate discussion among preservice science teachers at Vanderbilt University. According to Goldman and Barron (1990), preservice teachers who used the interactive videos in their methods class improved considerably in classroom management practices and in several instructional strategies such as development of problem solving skills and higher order cognitive skills.

The use of interactive video technology provides the learner with the opportunity to go back over scenes and review the events. This can be particularly useful in problem solving exercises in which the person is unable to note and remember all of the pertinent information relevant to the solution of the problem. It is also possible to "mark" a certain point on the computer monitor or to make measurements of events shown by the image on the videodisc.

Events which take an inordinately long or short time can be slowed or speeded up for more meaningful and reasonable observation within the time and facility restraints of the classroom. Dangerous and otherwise inaccessible systems can be accessed and manipulated through computer and videodisc technology. This allows students to experience events that would otherwise be beyond their realm of personal experience by providing a concrete, personalized experience to better understand important concepts in science.

Level-3 Interactive Video Design Issues

The design of level-3 interactive video raises three interesting questions about the use of computers in education:

1. What role should the teacher, the student, and the computer play? For example, Hyperscience contrasts with traditional approaches to computer-aided instruction (CAI) in that the teacher is actively involved in the ongoing activities, probing, providing feedback, motivating, and directing discussions. Although, like traditional CAI, Hyperscience provides a question and an answer, the teacher's role is enforced because students do not enter an answer on the computer. Rather, they discuss their ideas with the teacher. Thus, teachers can ask questions such as "What do we know about this event?" "What do we need to find out?" and "How are we going to find out?" in order to encourage students to perform

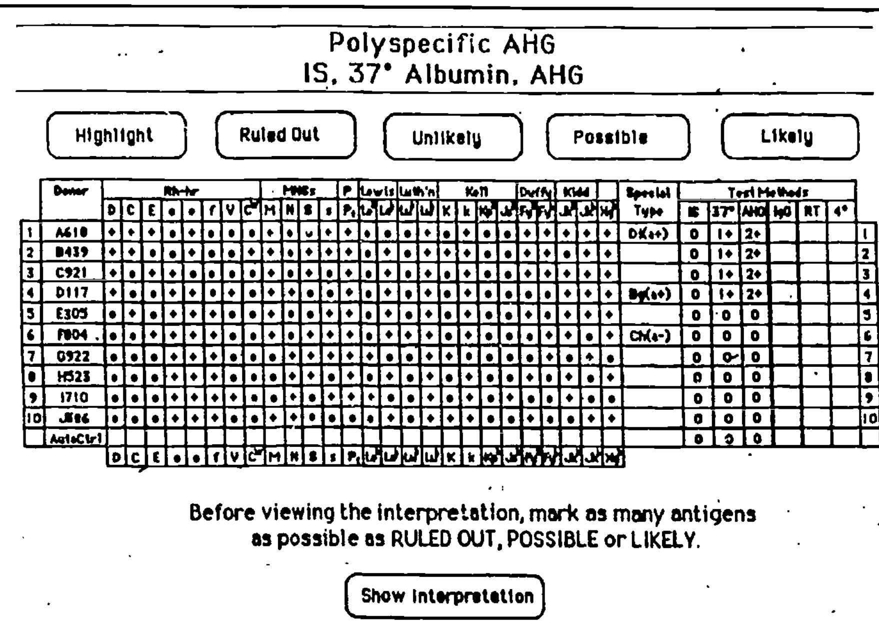

Figure 6. Sample TMT data display

their own investigations and arrive at possible explanations. In addition, after developing the relevant background, the teacher may pose questions such as "How can we use this information?" and invite learners to explain their answers and responses to the class for further discussions.

2. Does observing video of an event (as opposed to the text-based description of the event) stimulate and enhance reasoning and problem solving about that event and also lead to better long-term retention of lessons learned? In other words, does the display medium affect the learning process?

3. How does embedding problem solving in a concrete setting through presenting the problem episode in a video (as opposed to an abstract description of the relevant phenomenon) improve learning?

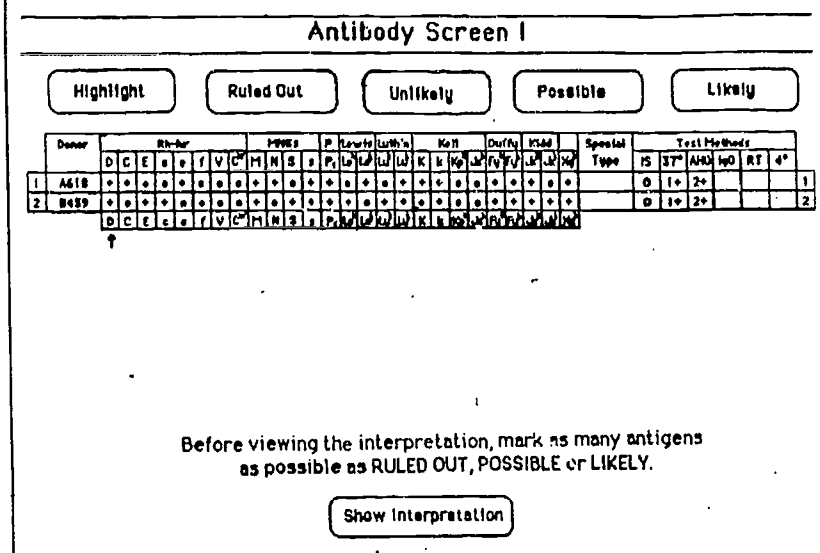

Figure 7. Sample dislay of the feedback to student

An Intelligent Tutoring System

To highlight issues associated with the design of ITSs, consider the Transfusion Medicine Tutor (TMT). Written in C and running on a Mac II with three color monitors, TMT provides a problem solving environment similar to GAIT. In the case of TMT, however, the problem solving task is the identification of antibodies in a patient's blood. This is a complex abduction task in which masking and noise combine to pose a challenging problem solving task (Smith, Galdes, et al, 1991).

The left screen displays the tests normally available to a technologist in a transfusion laboratory as shown in Figure 6 (Smith, Miller, et al, 1991). The center screen displays the particular test result selected for viewing from the set of tests on the left screen. (See Figure 7 for an example). The right screen is used for selecting a final answer and for tutoring. (See Figure 8).

When data such as those shown in Figure 7 are displayed on the center screen, the student can mark intermediate conclusions in a manner analogous to markings presently made on paper in the laboratory. He/she can highlight data, mark antibodies as ruled out, etc. As a memory aid, these intermediate conclusions are propagated from one test to another as the student explores various test results.

TMT differs from GAIT in that it has an expert system embedded in its architecture. This expert system monitors the student markings (intermediate and final conclusions) and provides feedback in response to errors. It also provides a discussion of an expert's interpretation of any given set of data upon request.

Due to recent concerns related to the transmission of blood related diseases it is no longer reasonable to conduct blood typing activities in biology classrooms using the students' own blood. Use of this technology as in TMT enables students to explore blood typing in a safe environment.

Tutoring Function

TMT monitors student inferences and requests for data. These actions are used to detect errors (actions that run contrary to those of the expert model). Examples of such tutoring behaviors are categorized below.

Inappropriate Test Selection. One class of actions performed by the student is a request to run a particular test. TMT uses the data currently available to the student about that case, plus its knowledge about the appropriate use of tests, to assess such decisions. If the student has requested an inappropriate test, TMT detects the error and interrupts the student. The interruption consists of a caution and an explanation of the basis for this caution. TMT also provides suggestions about what to do next.

Testing for Understanding. Preliminary studies of student performances indicated that students sometimes know enough to ask for the right test but not enough to fully interpret the results. Our expert human tutors frequently

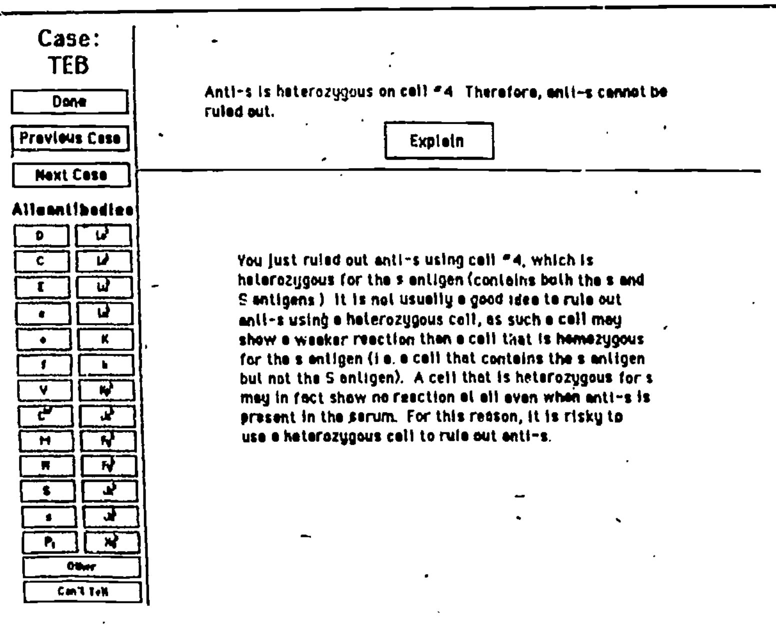

Figure 8. Message in response to an erroneous rule-out

detected this by asking a question at the appropriate point. TMT does likewise, presenting multiple choice questions at points where students are likely to have misunderstandings.

Erroneous Intermediate Conclusions. TMT also monitors for errors of omission and commission. Since the student can mark intermediate conclusions on the displayed data sheets, TMT can check to see whether the appropriate conclusions have been drawn. TMT monitors for two types of errors: Drawing an incorrect intermediate conclusion (such as incorrectly ruling out an antibody) and failing to draw a conclusion that the data support.

Erroneous or Questionable Final Conclusions. TMT also looks at the student's final answer (indicated by clicking on buttons representing possible antibodies) and critiques it. If, for example, the student has concluded anti-C is present alone in a case where anti-C and anti-D are present, the system will point out the error. As part of this critiquing process, TMT teaches the student methods for detecting his/her own errors.

TMT Design Issues

The design of TMT raises a number of important questions. First, like the design of Hyperscience, the role of the teacher must be defined. Informal evaluations of the TMT suggest that its most effective use is not as a stand-alone teaching system, but as a learning environment in a laboratory setting, where the teacher can circulate among students working on TMT, asking questions, and providing assistance.

A second issue involves how to design a system that can detect students' errors in a timely fashion. The interface to TMT was explicitly designed to enable such error detection. Because students have to request specific pieces of data and draw intermediate conclusions, TMT can detect many errors immediately without being intrusive. Other types of naive conceptions are handled by having the system actively probe with a question. A third issue is the question of when to interrupt given that an error has been detected. Empirical studies of expert human tutors suggest that such decisions involve complex reasoning (Galdes, Smith & Smith, 1990) which is beyond TMT's current capabilities.

A fourth issue is raised by the use of the colored arrows used as feedback by TMT (in Figure 7). The philosophy behind this design feature is that students should be given the opportunity to develop their own explanations before looking at the computer's (Chi, Bassok, Lewis, Reiman, & Glaser, 1989).

A fifth issue concerns the adoption of alternative learning strategies by students. Will they simply look at the computer's answer or will they try to interpret the data on their own first? What will they read of the computer's explanations? How do we influence them to adopt effective learning strategies and help them modify their own learning strategies to be effective? The literature on how people use documentation suggest that these are nontrivial concerns (Wright, 1983). Multi-media feedback may be part of the answer.

Future Directions

The advanced technologies discussed above offer two approaches to enhance learning. Midro, Chioccariello, Olimpo, Perisco, Sarti, and Tavella (1988) suggest that the integration of these technologies can alleviate many of the shortcomings of hypermedia (including level-3 interactive video) and intelligent tutors and lead to the development of more intelligent and flexible systems capable of making teaching and learning more efficient and meaningful.

Currently emerging technologies add yet further promise of increased flexibility and efficiency. One example is the pen-based computer. These computers are completely wireless, responsive to handwritten input, and capable of interaction with other systems. The applications of this technology with its wireless portability and reduced interface barriers are just beginning to be explored. It seems clear, however, that the instructional potential of the pen-based computer is high, particularly when combining it with other approaches such as hypermedia and intelligent tutoring systems.

Conclusions

The use of hypermedia (including level-3 interactive video) and the integration of "intelligence" into tutoring systems represent two important approaches for enhancing the use of computers as educational tools. To date, however, most of the effort has gone into exploring the implementation of such systems in attempts to identify alternative capabilities and uses of these technologies. The result has been a number of interesting models. Informal evaluations indicate that these approaches can offer significant improvements over traditional uses of computers in education. As outlined in this paper, however, there are numerous questions which remain to be answered in order to develop an empirical basis for guiding the design of such learning environments. For example, Clarke (1990) in a review of computer usage found sex discrimination favoring male students. To what extent this discrimination is revealed with these advanced systems remains to be determined.

GAIT, Hyperequation Project, and similar ongoing projects are relatively novel applications of hypermedia in developing alternative science assessment technologies. Hyperscience 456 and Teacher Education Project may be classified as examples of learning with computers (Luehrman, 1982 February & Luehrman, 1982 September) and one of the most useful applications of "level 3IVD" systems. The Transfusion Medicine Tutor, an example of building intelligent tutors using expert systems technology, is a very promising practical application for science education.

Such systems are nothing more than advanced technologies. Therefore, how they are used in science instruction will determine their future success in education. The applications presented in this paper are a glimpse of what these advanced technologies can do for education. These technologies offer great hope for science education of tomorrow and offer the potential to transform science learning into a meaningful, interesting, and practically relevant experience. To accomplish this goal, however, we must go beyond the implementation of interesting systems. We need to use such systems as testbeds to collect empirical data on the effectiveness of the underlying design concepts.

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