Problem-Based Learning: A Case Study in Integrating Teachers, Students, Methods, and Hypermedia Data Bases

by

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Dissertation submitted to the faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Curriculum and Instruction

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July, 1993
Blacksburg, Virginia

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(ABSTRACT)

This study describes two efforts: (1) the development of a learning environment that includes a hypermedia data base about Mesoamerica, and (2) an observational study of middle school students using the system within a framework of problem-based learning for mastering content and thinking skills. The goal was to create a learning environment influenced by metacognitive strategies, hypermedia interface design, and problem-solving scenarios preceded by discrepant events. Participants consisted of 25 seventh-grade social studies students. They were divided into four groups, each having access to a microcomputer with the hypermedia data base. They also had additional resources such as books and magazines dealing with Mesoamerican civilizations. Data collection included direct observations from four facilitator/evaluators, audiotape, videotape, student products, software routines, and questionnaires. Findings suggest:

- the hypermedia data base navigation was usable and easy to learn for these students
- a discrepant event inquiry model was among the factors contributing to sustained student activity
- embedded problem-solving strategies facilitated higher-order thinking only when coupled with teacher support.

The key in the environment appeared to be teacher-student interactions which allowed the teacher to dynamically assess students' abilities, then provide necessary support for independent action. The computer's role was that of a tool which mediated between the teacher and students.

Acknowledgments

My association with the faculty and students at Virginia Tech has been personally and professionally rewarding. I was fortunate to have a chair such as Dr. John K. Burton who provided opportunities to publish and kept my naiveté from getting me in too much trouble. Dr. Deborah S. Hix and Dr. Susan G. Magliaro provided sound advice, especially with my writing and research. Dr. D. Michael Moore and Dr. C. David Taylor asked tough questions at formal meetings, as I hoped they would. Dr. James G. Garrison was invaluable in pointing me in the right direction concerning philosophical underpinnings of the learning-teaching scenario. Dr. Norman R. Dodl provided equipment for this research, and like Ms. Terry L. Stevers was patient and resourceful throughout our association.

Mrs. Carolyn B. Cox deserves special gratitude for her trust, inspiration, and access to her classroom of 25 seventh-grade students whom we exposed to the unique aspects of pre and post Colombian Mesoamerica.

No doctoral program is complete without fellow travelers in pursuit of growth. I sincerely hope my future includes continued association with Denny Buckwalter, Mark Childress, Richard Croft, Bill Jaber, Jamie Little, Yvonne Liu, Glenda Rose-Scales, and Laurie Ruberg.

My family deserves a medal for all those times I turned into a computer hermit as I prepared the database and worked on this document.

I was very fortunate to have Dr. Steven L. Purcell as a fellow graduate student. His technical and methodological advice were invaluable; the energy, drive, and enthusiasm he displayed were a constant source of motivation.

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Chapter 1

Introduction

This document describes two efforts: (1) the design of a learning environment that includes a hypermedia data base about ancient civilizations in Mesoamerica, and (2) an observational study of middle school students using the system within a framework of problem-based learning for mastering content, and learning valuable critical thinking skills. One frequently reads calls to address problem-solving and higher-order skills of students. Statements of these types have been with us for some time. This quote from Benjamin Bloom (1956) is a prime example:

> Whatever the case in the past, it is very clear that in the middle of the 20th century we find ourselves in a rapidly changing and unpredictable culture. It seems almost impossible to foresee the particular ways in which it will change in the near future or the particular problems which will be paramount in five or ten years. Under these conditions, much emphasis must be placed in the schools on the development of generalized ways of attacking problems and on knowledge which can be applied to a wide range of new situations. That is, we have the task of preparing individuals for problems that cannot be foreseen in advance, and about all that can be done under such conditions is to help students acquire generalized intellectual abilities and skills which will serve him well in many new situations. (p.46)

This document discusses development of a system to address Bloom's concerns. Because an integral part of this system includes design and development of a thematic hypermedia data base, the first two chapters discuss issues involved in its creation. Later chapters explore integrating the data base into a classroom and conducting a study to determine the success of these efforts.

The term multimedia has many definitions — depending upon the background of the person doing the defining. In its simplest form, multimedia can be described as a combination of two or more electronic forms of communication. A more descriptive definition includes a system that combines video, text, sound, animation, and graphics.

Hypermedia employs the same electronic forms as multimedia, but allows learners to access information in nonsequential fashion. An elaboration of hypermedia follows.

In 1945, Vannevar Bush hypothesized a device called "memex." Memex would provide storage for various print media, then allow users to rapidly retrieve the information. With Memex a user could search in a nonlinear fashion by creating links or associations among ideas. Nelson (1967) coined the term "hypertext" which permits users to connect ideas in a nonsequential fashion. Nelson is also credited with defining "hypermedia." Hypermedia goes beyond hypertext to provide nonsequential or nonlinear links involving multiple forms of media such as full motion video, audio, still frame pictures, and animation. Both terms, multimedia and hypermedia, are used in this document. They refer to nonlinear navigation through the data base.

Efficacy of these systems causes continuing debate. While this issue is somewhat outside the focus of this document, a short review of the debate is warranted. It is difficult to find educational technology periodicals that fail to address some facet of hypermedia or multimedia-based systems. Educators and researchers continue to question the effectiveness of these new systems in learning environments. Proponents say multimedia allows learners to create, annotate, and link together information from a variety of media such as text, full-motion video, animation, and sound (Meyrowitz, 1988). Advantages are said to include the possibility of combining artificial intelligence, cognitive science, and advanced technologies to provide a quantum jump in learning (Molnar, 1988). Ambron (1988) states that multimedia frees teachers from the constraints of textbooks and allows students to be active learners, controlling access to and manipulating vast quantities of information with a computer. Amthor (1991) states that multimedia arouses curiosity, promotes self-propulsion, and organizes knowledge by mirroring human activity.

Intuitively, giving students the ability to traverse large multimedia information stores could result in more motivated and knowledgeable students. Self-acknowledged visionaries proclaim the dawning of a new Renaissance, but perhaps ignore the basic processes of learning (Purcell & Myers, 1992). Reeves (cited in Sheehan, 1992) suggests that "interactive multimedia does not guarantee learning anymore than the presence of a library on a campus or in a school guarantees learning" (p. 21). Reeves calls for a return to pedagogy and design which will support learners' interaction with multimedia. Basic questions still remain, for example, how does this type of media create the attention and motivation necessary for retention and comprehension?

Reservations about this technology abound. Some think it possible that learners will have such a trail-rich environment that it is dysfunctional to the learning process, leaving the user disorientated (Conklin, 1987). He states that a good navigational system must tell where the users are located and how to get where they want to go. He also suggests that it may be difficult to carry the mental load required to create, name, and keep track of links or trails. Heller (1990) adds that flagging commitment and unmotivated rambling may result. The enthusiasm about multimedia carries some risk. Bosco (1989) warns that multimedia can easily be used in trivial or ineffective ways, and it is too easy to get wrapped up in the technology as a thing unto itself. The penalty for this enthusiasm could involve a number of undesirable impacts. First, it could lead to undelivered promises. Second, it could cause a failure to take a critical look at technology. For example, does multimedia have, or will it have, the ability to affect the learning process in a positive way? If multimedia advocates are right, then typical questions remain. For example, what types of learners will best profit from multimedia, and under what circumstances?

Why haven't schools taken to multimedia faster? Many reasons exist. Costs may dissuade schools from using multimedia. Time is one cost. For all the advances in software, it still takes a considerable amount of time to become adept in using development packages. In addition, few people have the combination of skills required to develop excellent (or even average) multimedia packages. Lack of funds has to rank high on the list of reasons as well. Typically, a multimedia system requires two monitors, special interface cards, and an assortment of cables, players, and software. Until the costs of systems fall, and system requirements narrow to one standard unit, many schools may stay on the sidelines. Other extremely important issues are consideration of the learning environment, the types of students, and the situations that would benefit from multimedia.

Multimedia in Action

Despite the cautions raised above, there are many bright spots in multimedia. One of the early examples of multimedia design is the Palanque project. This prototype, developed jointly by the Bank Street College of Education and the David Sarnoff Research Center (Wilson, 1990), takes a multidisciplinary approach toward discovery-based learning experiences. Its aim is to evoke student subject matter curiosity while being fun and easy to use for 8 to 14 year-old students. One unique aspect of Palanque is the surrogate travel feature which allows the student to tour an ancient Mayan site in Mexico. Capabilities include the ability to climb in and around the temple, zoom in for close looks, listen to an archaeologist, or hear sounds of the local rain forest. Students can create a scrapbook of pictures from the site. These provide students the ability to put together subject matter presentations.

How could multimedia work in the classroom? A middle school student might be interested in the Apollo project and the first lunar landing. Using optical disc libraries, the student can learn about early winged-aircraft research, then shift to the ballistic missile program the United States started after Sputnik. The student could view laser disc video segments of space firsts — to include lunar landing sequences, then read and capture CD-ROM accounts about the space program. Next, the student could make a multimedia link to related stories about subsequent development of the shuttle program. Audio segments from various Presidents could also be integrated into a personalized package that the student could present to the whole class. A slightly different twist to this scenario could involve a collaborative group of students, working together to capitalize on different points of view and levels of subject matter expertise.

Multimedia is making inroads into training in the business setting. One major insurance company reports instituting a company-wide training program using various video disc based programs (Curtis, 1990). One advantage of video disc programs for a national firm is that industry-specific training may be developed for a heterogeneous population distributed over a large geographic area. Another benefit provides consistent training any time an agent wants to use the material. The company reports that training takes 30% less time and has contributed significantly to employee retention. It also reports sales increases for first-year agents and a significant reduction in training costs.

Are times changing? As of this writing, at least two states (Texas and California) have adopted curricula materials based on multimedia (A First, 1991). This has come about in part because newer hardware and software are both more powerful and less expensive. The features it provides may encourage teachers to devote some effort to becoming proficient in its usage. Another favorable aspect is that there are now hundreds of educational laser discs and CD-ROMs available and more on the way. A teacher can take advantage of the myriad of commercial and public domain programs in existence.

There will arise many situations in which a group of students clusters around a workstation in pursuit of some learning objective. Most of the questions posed above remain, but now research concerning cooperative learning and its usage in a multimedia environment comes into play. This raises questions about whether to change the schools' structure from its traditional "one teacher and many students" orientation? A new model pictures the teacher as more a mentor, guide, or fellow traveler in the realm of multimedia. If multimedia and cooperative learning provide positive results, won't there be a significant resistance to change — especially from the established order?

Authority figures, the teachers, may feel some unease about their role in this. Will there be a loss of identity if the teacher is not viewed as the subject matter expert? What about the noise and confusion sometimes found in cooperative learning with technology? Isn't this anathema to good order and discipline? For some time teachers have charged that they are merely the delivery person of prepackaged curricula and that they don't have ownership over the topic or the content of their instruction (Wolk, 1991).

Do students learn more effectively or efficiently in a multimedia environment? The jury is still out (Schulz, 1991). We can quote books-full of testimony about the efficacy of multimedia in the classroom, but we can also quote those who either are undecided, or worse yet, state that multimedia does not enhance the learning process. Much research remains to be completed regarding multimedia in education.

What remains to be done? The comments from Reeves (cited in Sheehan, 1992) above provide some guidance. One of the answers is to provide excellent multimedia products, designed and developed to meet users' needs. The next chapter outlines considerations for student metacognition and navigation of hypermedia data bases.

Chapter 2

Design Issues

Hypermedia offers a rich environment for exploring a subject area. Users have opportunities to link information nodes in non-sequential sequences (Conklin, 1987). Along with the capabilities, designers must contend with a myriad of usability issues. For example, users have been known to experience cognitive overload, or explore only the surface of the data base (Conklin, 1987). Two design features are introduced as possible assistance, especially for novices or young users, in overcoming problems in use and navigation. The first concerns the embedding of strategies in the data base to get learners to think about their own learning and problem-solving processes. The second explores the use of iconic agents to assist with navigation.

Pilot Study

One way of enhancing success of new technology is to optimize the human-computer interface. The interface can be described as the means by which computers and users communicate. With a usable interface, learners can concentrate on the task at hand instead of contending with a plethora of semantic and/or syntactic system inarticulateness. A pilot study (Myers, 1991) provides insight to problems faced by learners using hypermedia.

Participants in this pilot study were using the popular educational and entertainment software, *Where in the World is Carmen SanDiego*. Educational benefits of this game include learning note taking, planning, solving problems, using external resources, and learning about the characteristics of other countries (Myers, 1991). The object of the game is to catch an international crook. Players (usually between the ages of 8 to 11) are told by the program about the theft of some priceless object somewhere in the world. For example, players could be told that a painting had been stolen from the

Louvre in Paris. Graphics displayed by the program would show such things as the Eiffel Tower; information about Paris or France would be presented. Players are then given a time limit to catch the crook and the chase is on! The crook always leads the young detectives to four or five countries before game resolution. Players cannot anticipate destinations of the crook; the software creates the game and destinations at random.

Players are shown possible flights out of the original city (the crook will have gone to one of these destinations). Players are also given clues about the crook and about the crook's city of destination. The object of the game is to properly follow the crook in order to make an apprehension. Now how does all of this relate to hypermedia?

Like hypermedia, the Carmen game has potential pitfalls. The user in the Carmen game could make many jumps, then become disoriented or lost. Where in the world, for example, *are* Kathmandu, Port Moresby, Moroni, or Kilgali. Is the crook really at one of these exotic places or somewhere else? Not only could the player become disoriented, but after two or three hops, the player's seven plus or minus two short-term memory slots (Miller, 1956) could easily be overloaded. After letting the crook get away several times, the participants in this particular study changed their strategy. They took more notes and used the *World Almanac* to assist in gathering information. A modicum of success followed their new methods. Could the program have been designed in such a way that users did not have to suffer initial failure? Perhaps failures experienced in a game are acceptable, but in an environment specifically designed for learning, failure may dissuade learners from further participation, especially for those low in self-esteem or domain knowledge.

Designing the Interface

How *do* we design the hypermedia "interface." An interface consists of those visual and audio cues that allow us to use the system. Menus, beeps, maps, buttons, and icons are some of the items that make up an interface. While an increasing amount of attention is being paid to construction of the user interface, much of the past research has offered only heuristics about design. One will commonly find such statements as: use white space, avoid scrolling, and maintain consistency. Perhaps more germane are questions posed by Meyrowitz (1988): what is the best way to organize links, symbolize links, or visually represent the network of links?

Discussion of representing links may evoke images of menus and other forms of navigation. Learners range from first-time users who are unfamiliar with the system, as well as the content, to those who have used the system frequently. Navigational options may have to change based on users' experience level. Another issue is the number of trails available to the user. Conklin (1987) cites a trail-rich environment as a potential place for cognitive overload. He states that a good navigational system must tell learners where they are located, and how to get to the desired place.

Suggestions for interface means to assist educational learners follow. The first concerns learners' awareness of their own knowledge and ability to understand, control, and manipulate individual cognitive processes. This awareness is generally referred to as "metacognition" (Brown, Bransford, Ferrara, & Campione, 1983; Flavell, 1979; Flavell & Wellman, 1977; Reeve & Brown, 1984). The second means suggested for learners is that of prompts and cues in the form of agents. These provide learners assistance in navigation as well as metacognitive skills.

Metacognition

Hawkins and Pea (1987) suggest that learners must recognize the profitability of spending effort in learning new thinking strategies. A profitable area to begin would be to assist learners in "knowing about knowing." Jacobs and Paris (1987) list three reasons for the importance of metacognition: (1) self-learning strategies require active participation on the learner's part, (2) interviews with students show that they knew very little about self-analysis and inquiry techniques, and (3) metacognition offers alternatives to traditional instruction. In line with emphasis on metacognitive skills in this chapter, Costa (1991a) suggests evaluation must become internal for students; we must remind ourselves that the ultimate purpose of evaluation is to have students become self evaluating.

Garner and Alexander (1989) cite research which shows that metacognition develops with age and experience. They also discuss ways to enhance "cognitive strategies (used to *make* cognitive progress) and metacognitive strategies (used to *gauge* cognitive progress)" (p. 145). The authors suggest that learners who are low in domain knowledge can use general strategies to compensate. They also submit that cognitive strategies and metacognition can be enhanced with instruction. The notion of training these skills is important. Many students have a mistaken belief that their failures are due to innate characteristics and that their intelligence is fixed (Greeno, 1989). Garner and Alexander (1989) state: "Without high esteem, an internal locus of control, and the tendency to attribute success to effort, students are unlikely to invoke complex cognitive and metacognitive routines to improve learning" (p. 146). Fortunately, the authors cite researchers who show that students who believe they are low in ability can be redirected to believing that more effort will result in success. Given more appropriate strategies, these students "initiate and persist at strategic activity...they understand, remember, study...more effectively" (p. 152).

Osman and Hannafin (1992) cite research which suggests that metacognition is integral to successful learning, but current instructional design (ID) models fail to address this important issue. Just as importantly, Brown and Palincsar (1982) say that learners fail to generalize metacognitive skills without instruction as to when and why to use them.

Metacognition has been roughly described as knowledge about cognition and cognitive phenomena (Flavell, 1992). Hedberg, Harper, & Brown (1993) describe it as "...about knowledge, skills, judgments of task difficulty and effort, beliefs about ability, worth of strategies, use of failure and purpose for performing tasks" (p. 3). Flavell (1992) discusses several components of metacognition. The first is "metamemory" which is defined as learners' knowledge of the self and others as learners and rememberers, knowledge about the memory tasks people perform, and knowledge of the strategies used to perform these tasks. Osman and Hannafin (1992) cite research which supports a relationship between metamemory and successful performance. They contend that learners will use a strategy when they are given detailed information about how and when to use it. The goal, say Osman and Hannafin is to assist learners in automatizing metamemory skills.

The second component of metacognition is "metacomprehension." It is defined as a conscious process of knowing about comprehending and knowing how to comprehend. The third is "self-regulation", defined as fine-tuning by learners in response to, or in the absence of feedback. The fourth, "schema training", facilitates comprehension by providing required background knowledge structures (Hannafin & Rieber, 1989). And last, "transfer" facilitates the learners' use of metacognitive strategies in similar circumstances (near transfer) and dissimilar circumstances (far transfer).

Self-attribution theory plays an important role in metacognition. Those learners with high self esteem and self-efficacy are more likely to believe in using strategic measures for application in complex situations (Hedberg, Harper, & Brown, 1993). To foster learning, transfer, and ultimate automatizing of metacognitive strategies, Osman and Hannifin (1992) suggest designers must either embed metacomprehension strategies within lessons to reduce cognitive load, or provide an opportunity for the learner to learn and practice skills in other subject matter domains. They provide guidance for design of strategies within instruction. Strategies may be detached or embedded in the lesson. They can also be content-dependent or content-independent (See Table 2-1).

Table 2-1
Classification Matrix for Metacognitive Training Strategies (Osman and Hannafin, 1992, p. 91)

Training Approach	Relationship to Lesson Content: *Content-Dependent Strategy (CDS)*	*Content-Independent Strategy (CIS)*
Embedded (E)	ECDS are specialized, task specific strategies applicable to particular content. They are design-centered strategies that emphasize near transfer.	ECIS are general learning strategies incorporated within available content to be learned. These strategies support local learning but emphasize strategy transfer as well.
Detached (D)	DCDS are general learning strategies that are taught separately but subsequentially applied within particular contexts. DCDS usually promote somewhat more transfer than ECDS, but the goal is typically to support a particular lesson.	DCIS are generalizable strategies that have applications across learning tasks Both learning content and contexts are varied. Lesson content role during training mainly to provide representative range of application. The emphasis is on far transfer.

Osman and Hannafin provide additional implications for instructional design:

- Metacognitive strategies should not compete for task-essential cognitive resources.
- Younger learners and novices require more explicit strategies. Higher-order strategies are appropriate for older learners and those well versed in a domain.
- If embedded strategies are used, but transfer is needed, identify procedures, then explicitly implement them.
- If high-road transfer (transfer to a different situation, content area, or domain) is desired, emphasize connections within and beyond lesson information.
- Supply prompts to aid learners in monitoring the depth at which they are processing instruction.
- Encourage interaction between learners.
- Be careful that the learners don't come to rely solely on the embedded prompts so that transfer can be made to situations outside the lesson (pp. 94-96).

Guides

As mentioned previously, potential hazards abound in an extensive data base (Conklin, 1987; Halasz, 1988). A primary concern is that navigation after a short period of successive jumps may disorient learners. A second problem is that potential expansiveness of a data base may cost so much in cognitive ability that users have little left for mastering the content at hand. To assist the novice or low-domain learner, the interface can provide useful assistance in answering: "what should I look at next", or "what's my best choice?"

Laurel (1990) recommends use of an agent, defined as a character who acts on behalf of the learner. Laurel, Oren, and Don (1990) found that "the use of *interface agents* reduces the cognitive load for users" (p. 136). While Laurel cautions that learners who do not need a guide, should not have to use one, it may be prudent to expect that most seventh graders (the participants in this study) new to a historical data base will need guides or agents. Table 2-2 lists likely tasks of agents:

Table 2-2:Agent Tasks (Laurel, 1990, p. 360).

Information	Work
Navigation and Browsing	Reminding
Information Retrieval	Programming
Sorting and Organizing	Scheduling
Filtering	Advising
Learning	**Entertainment**
Coaching	Playing against
Tutoring	Playing with
Providing Help	Performing

Laurel says the agent must have three characteristics. First, it must be responsive — quickly fulfilling its role of a social contract. Second, it must be competent in knowing about information content as well as retrieving that information. Last, it must be accessible. This means users must be able to predict what the agent is likely to do.

Laurel suggests that because learners have internalized dramatic conventions, even a one dimensional character can be believable.

Oren, Salomon, Kreitman, & Don (1990) discussed implementation of guides (agents) within a historical data base. Guides they used provided learners with a list of "choices" (most likely next moves or selections), the first of which was the default. Guided tours were also provided by Oren et al., but these apparently were not used by learners — much to the chagrin of the developers. Of more use were animated maps which provided a means of showing historical changes in an animated, graphical manner.

How should agents or guides be implemented? Laurel, Oren, and Don (1990) discuss a model that uses agents represented by timelines, animated maps, an article index, tours, and guides. Their guides were portrayed as graphic images with text, as iconic images, and as a video character.

A good example of the use of the above recommendations about agents can be found in *The Civil War Interactive Project* (Fontana, White & Cates, 1993). Their project uses the multimedia data base from the documentary, *The Civil War*. Of importance to this discussion, this development uses an anthropomorphic coach to model inquiry skills, cooperative learning, and assistance in problem-solving.

Summary

Two design issues have been presented. The first is to incorporate metacognitive strategies to assis learners. The specific strategies will be presented in the next chapter. Briefly, the strategies will be designed to provide users with advice about solving problems and a format for evaluating the process. The second design issue is the use of agents to assist users in such tasks as navigation. The agents' purpose is to provide novices and young users with choices in making associative links within the hypermedia data base.

Chapter 3
Higher-Order Thinking and Structured Inquiry

> Educators share a common interest in promoting higher level thinking and conceptual understanding in students. This is a timely interest as various national and international assessments point to the fact that our students lack the knowledge and reasoning skills necessary for effective functioning in the Information Age. These tests show, for example, that only a small percentage of our high school graduates are capable of complex, multi-step reasoning in mathematics (Dossey, Mullis, Lindquist, & Chambers, 1991) or can function at an advanced level in reading, which involves being able to extract ideas from complex pieces of writing (Mullis & Jenkins, 1991). It is not surprising, then, that our students lag far behind those in other countries on items measuring complex thinking in all curriculum areas (Prawat, 1991, p. 3).

How do we get students to solve problems, think critically and creatively, make inferences, plan, hypothesize, generate independent solutions, and/or make decisions? These processes may need supporting activities such as "...defining situations, setting goals, formulating plans, comparing alternative courses of action, judging difficulty, apportioning time, and monitoring results" (Prawat, 1991, p. 4). Quellamalz (1991) provides a list of activities for students engaged in purposeful, extended lines of thought:

- Identify the task or problem type.
- Define and clarify essential elements and terms.
- Judge and connect relevant information.
- Evaluate the adequacy of information and procedures for drawing conclusions and/or solving problems. (p. 339)

A recurring issue is how we teach learners these skills. There is a wealth of literature on these questions, but the answer appears to be that we teach them (Ennis, 1987; McTighe & Schollenberger, 1991; Resnick, 1987; Sternberg, 1984). Perkins (1986) suggests that we try to teach too much content to the neglect of those tactics needed to become better thinkers. In fact, Perkins avers that good thinking is an unnatural act. It is unnatural, he suggests, because, if left alone, human thinking tends to manifest the following three weaknesses:

1. Biased versus evenhanded reasoning: People take egocentric approaches to issues that fail to explore the "other side" of the issue, thus incorporating biases into their thinking.

2. Problem-solving versus problem finding: Learners tend to suggest solutions to a situation before adequately determining the nature of the problem.

3. Knowledge as information versus knowledge as invention: Learners treat abstract knowledge as information. For example, students may view Columbus's discovery (or re-discovery) of the new world as information instead of looking at the historical context in which his voyages took place. Learners might consider, for example, social, political, and economic conditions that led to a need to explore new routes to the East.

Perkins recommends using "thinking frames'" as a guide to redirecting thinking into better patterns. A thinking frame is defined as "...a representation intended to guide the process of thought, supporting, organizing, and catalyzing that process" (p. 7). The frames are divided into two types: (1) those that relate to thinking processes such as self-questioning, using headings to guide readings, and mapping key relationships, and (2) those that relate to its products. The latter is a form of "critical thinking" that gives students means of evaluating their own ideas (Woolfolk, 1993). Perkins lists three major themes in developing thinking frames: acquisition, internalization, and transfer. Acquisition may be enhanced by directly teaching the frames to learners. Internalization comes with practice. Perkins recommends starting slowly, practicing, and avoiding the tendency to escalate complexity too soon. These suggestions help avoid overloading short-term memory. He also suggests using reminders or memory supports to get students to use new techniques. (This suggestion falls in line with use of embedded metacognitive guidance and agent support as discussed in the previous chapter.) Transfer may be enhanced by requiring students to use these skills in other contexts.

Prawat (1991) says that the most prominent technique of teaching thinking skills is to embed skills into the curriculum — or within the context of specific subject matter domains. This method blends an equal balance of thinking skills and subject matter. The importance of this is that learning and thinking are thought to result from an interaction between a learner and a situation rather than something occurring in a person's mind (Greeno, 1989).

Another useful way of creating a context for learning is through "situated cognition" (Brown, Collins & Duguid, 1989; Greeno, 1989). Brown, Collins, and Dugid contend that students need more than abstract concepts and canned examples. They suggest that learning should be conducted in activity situated in real-life social, cultural, and physical contexts. Research conducted by the Cognition and Technology Group at Vanderbilt (CTGV, 1990) is a good example of the use of media (videodisc) to "situate" or "anchor" students within a learning environment.

CTGV submits that new information learned during meaningful activity is perceived as a tool rather than as inert information (information students have learned but will be unable to apply in appropriate situations). They attempt to attack the inert information problem with multimedia environments supportive of sustained exploration. According to them, this sustained exploration allows multiple perspectives and permits opportunities for teacher-guided discovery. Their problem-solving macrocontexts help students develop tools that form new, as well as modify old perceptions. This is in contrast to traditional instruction that emphasizes mere facts to be memorized.

Cooperative Learning

Students using this prototype worked in cooperative groups of six students. Johnson & Johnson's (1991) article suggests: "The interpersonal exchange within cooperative learning groups, and especially the intellectual challenge resulting from conflict among ideas and conclusions (i.e. controversy), promotes critical thinking, higher-level reasoning, and metacognitive thought" (p. 298). Johnson and Johnson (1985) link cooperative groups to technology: "Cooperative learning with computers (compared with competing with others or working independently at the computer) promotes more and better work, more successful problem-solving, and higher performance on factual recognition, application and problem-solving tasks" (pp. 12-13). Johnson and Johnson suggest these results occur, especially in heterogeneous groups, because of the exchange of diverse perspectives and ideas. Students can monitor each other's ideas and provide feedback about their reasoning. Piaget (cited in Chapman, 1988) would offer that joint activities can lead to construction of new knowledge that participants did not possess before. "In this sense", says Chapman, "inquiry can be considered a form of intersubjective equilibration with 'optimizing' possibilities" (p. 53).

Increased Teacher-Student Interaction

Sivin-Kachala (1993) discusses introducing technology into learning environments to facilitate student-centered and cooperative learning, and to stimulate increased teacher-student interaction. The theme of increased teacher-student interaction is important. Many researchers subscribe to the theory that learners actively construct their own knowledge structures. Newman, Griffin, and Cole (1989), in their book *The construction zone: Working for cognitive change in school*, agree with the concept of knowledge construction. The emphasis they suggest, however, that cognitive change occurs as a result of individuals' interaction in a social environment. They argue that inclusion of the social environment is a necessity for cognitive change. This theory is an outgrowth of Vygotsky's (Cited in Newman, Griffin, & Cole, 1989) theory of the zone of proximal development (ZPD). The ZPD is defined as: "The difference between the level of problem difficulty that the child could engage in independently and the level that could be accomplished with adult help. Cognitive change takes place within this zone, where the zone is considered in terms of the support structure created by the other people and cultural tools in the setting" (p. 61).

Central to the ZPD is the concept of "appropriation."[1] During a classroom scenario the teacher has some idea of where students are going. Students may or may not know where they are headed, but know there is a "functional system"(e.g., teacher, technology, other students, and additional resources), that is going to take them "somewhere else." Students would not use such an esoteric term as "functional system" of course. They are accustomed to the boundaries of the classroom environment and the role the teacher-student interaction will play in providing for cognitive change. The teacher-student interaction is actually a two-way exchange. The teacher finds "where the students are" in a particular domain through dynamic assessment, then facilitates getting students to "somewhere else." Students "get there", for example, by "appropriating" experts' skills and knowledge brought to the environment. In short, there is a negotiation between what students bring to learning situations and what the teacher has in mind. As the teacher evaluates the current state of knowledge or understanding, s/he, modifies or alters instruction to bring students closer to the intended state of understanding. A typical sequence might consist of these steps: (1) students engage in purposeful action toward a "new set of understandings"; (2) the teacher withdraws to the edge of the children's entry level (this is the lower level of the ZPD); (3) when the teacher determines "where

[1] Similar to Piaget's concept of accommodation.

students are" within this particular domain, s/he then begins to make use of those things in the functional system to provide expert assistance; and (5) the teacher slowly withdraws support as students come closer to the desired set of understandings. Although this is analogous to scaffolding, modeling and fading, it is a two-way process or interaction (Garrison, 1993). One unique aspect of this approach is that learning does not have to be hierarchical in nature; students do not have to enter the learning environment with all of the prerequisites skills, knowledges or understandings. Through the technique of "bootstrapping", the teacher and children could be interacting in the mastering of several tasks at all levels of the cognitive domain.

What is the role of technology and especially that of the computer? Newman, et al. suggest that it will be most effective as a tool, or variable within the functional system that contributes to the ZPD. In this study it was not envisioned that the participants would be computer literate — certainly not literate in using the hypermedia data base provided them. The students did not know how we expected them to use this data base, but we expected their knowledge about this tool to be transformed through appropriation. The computer would then become, in the context of Newman, Griffin, and Cole (1989), a culturally elaborated tool available for future usage.

Inquiry-based Model

As discussed above, we want students to solve problems, think critically and creatively, make inferences, plan, hypothesize, generate independent solutions, and/or make decisions. These goals are ambitious — especially for students who have had little or no introduction to goals of this kind. The benefits of resolving a problem are many; here is a quote from Dewey (1933) that succinctly addresses some of these benefits:

> The two limits of every unit of thinking are a perplexed, troubled, or confused situation at the beginning and a cleared-up, unified, resolved situation at the close. The first of these situations may be called pre-

> reflective. It sets the problem to be solved; out of it grows the question that reflection has to answer. In the final situation the doubt has been dispelled; the situation is post-reflective; there results a direct experience of mastery, satisfaction, enjoyment. Here, then, are the limits within which reflection falls (pp. 116).

The discussion in Chapter II established the basis for using embedded instructions to teach critical thinking skills. These skills will be developed as the students solve problems in an inquiry-based context. An observation from Wolf (1991) about how we traditionally assess the learner's knowledge sheds light on why an inquiry approach was chosen:

> The "surprise" nature of many test items, the emphasis on objective knowledge, the once-over and one-time nature of most exams — all offer students lessons that are destructive to their capacity to thoughtfully judge their own work: (1) assessment comes from without, it is not a personal responsibility; (2) what matters is not the full range of your intuitions and knowledge, but your performance of the slice of skills that appear on your tests; (3) first-draft work is good enough; and (4) achievement matters to the exclusion of development. (p. 351)

Students need to learn to evaluate their own work and develop in reflective abilities and knowledge. Learners construct their own knowledge structures; inquiry is a method that facilitates this process. Prawat (1991) and Brown, Collins, & Duguid (1989) state that unless students "work" with new knowledge, it just lies there, or remains inert. The former was arguing for the immersion approach to the development of thinking in which students' perceptive processes come to grips with "ideas." The latter were arguing for learners to learn in situated, real-world contexts. Both make the point that learners must wrestle with information in a meaningful fashion, else accommodation will not occur. Costa (1991b) suggests that learners must process and apply data, using "... significant skills in reflective thinking and go beyond the input-recall state, into higher levels of thinking" (pp. 302-303). Costa cites Bruner (1961) and lists two potential benefits of inquiry learning: (1) "an increase in learner motivation due to the intrinsic rewards of discovery, and (2) an increase in intellectual potency and development of aids to memory by helping learners organize material according to their interests and cognitive structures" (p. 303). Costa also cites Goldman (1968) who suggests that a main benefit of inquiry approaches is that they teach learners how to learn (a common theme throughout this document).

Equilibration

Before discussing examples of the inquiry model and events that facilitate their use, more groundwork is warranted. The first, and perhaps one of the most important theories in this document, is Piaget's theory of equilibration (cited in Chapman, 1988). Equilibration is defined as a search for a mental balance between the individual's cognitive schemes and information from the environment (Woolfolk, 1993). Chapman (1988) interprets Piaget to suggest that the drive for equilibration is manifested in an attempt to compensate for "perturbations." A perturbation could exist in the form of contradictions or *lacunae* (gaps in knowledge). Perturbations, according to Chapman (1988), result when subjects realize their knowledge is insufficient to reach a goal. Given Piaget's concepts of equilibration as a learner's goal, and gaps in knowledge as a perturbation, it is appropriate to introduce Festinger's work on cognitive dissonance.

Cognitive Dissonance

Festinger (1957) also averred that individuals strive for internal consistency. When learners experience inconsistencies, psychological discomfort results. Festinger's theory provides us with two elements: (1) "The existence of dissonance [inconsistency], being psychologically uncomfortable, will motivate the person to try to reduce the dissonance and achieve consonance [consistency]" (p. 3), and (2) "When dissonance is present, in addition to trying to reduce it, the person will actively avoid situations and information which would likely increase the dissonance" (p. 3). Festinger defined the term "cognitive" as any knowledge, opinion, or belief about the environment or oneself. Most importantly, Festinger saw cognitive dissonance as an antecedent condition which lead to activity toward dissonance reduction. Central to this argument is that introduction of new information may create cognitive elements that are dissonant with existing cognition. The final element in this line of thought is that dissonance gives rise to pressure for dissonance reduction; the strength of the pressure to reduce the dissonance would be a function of the magnitude of the existing dissonance. All that is needed is a means by which dissonance is created in learners.

Discrepant Events Within Inquiry

A current multimedia effort using an inquiry-based approach to affect students' higher-order thinking skills is that of Fontana, White and Cates (1992). The latter are attempting to present a design heuristic that will help learners master higher-order thinking skills through structured inquiry. Bruce and Bruce (1992) offer a similar model for inquiry within social studies. They want students to think logically, to develop philosophical and imagination skills, and discover lost curiosity. While both models are inquiry-based, that of Bruce and Bruce is structured purposely to ignite a spark (analogous to the dissonance cited above) that makes students "want to know."

The spark is created with presentation of a puzzling situation or event. Nussbaum and Novick (1982) state that in order for accommodation of a new concept to occur, students must first recognize a problem as well as their inability to solve it. Students' inability is brought about by presentation of a "discrepant event." A discrepant event is simply an inexplicable condition, statement or situation. The discrepant event creates a state of disequilibrium (or cognitive dissonance as discussed above). The key in Nussbaum and Novick's argument is that once students are in a state of disequilibrium, they are motivated by "epistemic curiosity" (Berlyne, 1965) to reduce the disequilibrium. Nussbaum and Novick (1982) suggest that traditional instruction seldom provides for students to experience cognitive conflict.

Bruce and Bruce (1992) suggest that logic-defying problems often make us feel disequilibrium. Motivation from the disequilibrium causes questioning, snooping, and searching to reduce uncertainty and re-enter a state of equilibrium. The Bruce and Bruce structured model takes learners through five phases:

(1) Discrepant event. Students read or are presented a discrepant event. From it, they generate a problem question. Discrepant events, or situations like them have received frequent attention in the social sciences. Costa (1991b) states that the inquiry method purposely creates situations to extend reflective thinking. Massialas, Sprague, & Hurst (1975) offer several devices to get students' attention and involvement. Their suggestion is to use "springboards." Springboards can take such forms as documents, magazine articles, graphs, and visual media. They cite a multimedia unit entitled *World History Through Inquiry* that draws from several disciplines to get students to examine and discuss issues. Massialas et al. also suggest using "puzzling documents" that lack critical facts and conclusions or include discrepancies.

(2) Generate questions. Students create a series of questions that can be answered with a "yes or no" response. Making them create a yes or no question causes students to organize their thoughts. This way the learners are probing for specific information instead of general, subsuming types of questions.

(3) Students gather data to answer questions about important variables and ask hypothetical and causal questions.

(4) Students analyze their information to reach a hypothesis.

(5) Last, in a metacognitive mode, students review the entire process.

Here is a typical scenario encountered by students:

I. Discrepant Event. In 1519 Cortéz, a Spanish sea captain with 550 men (including 32 crossbowmen, and 13 musketeers) and 16 horses, landed on the Yucatan Peninsula. This was the area of the Aztec, an empire that stretched from central Mexico to the present boundary of Guatemala. Within this area were 25 million people governed by Montezuma. Montezuma's capital city of Tenochtitlán quartered some 50,000 Aztec warriors. Within two years, however, Montezuma would be dead, Tenochtitlán would be in ruins, the empire would be in chaotic disarray, and the Spanish would control the area.

Students, assisted by problem-solving steps, would generate a problem statement. Massialas, Sprague, and Hurst (1975) suggest asking questions such as the following to generate the problem definition:

• What is this story really about? A possible answer is: the disaster that happened to millions of people when cultures, societies, and technology clashed.

• What seems to be the problem here, or is there anything unusual about what happened here? A possible answer is: it doesn't make sense that a few men in ships could make a whole empire fall.

Based on an analysis of the event, an typical problem statement might be: Did, and if so, how could such a small force of Spaniards cause such profound changes in the Aztec culture in such a short time? Now the students have a problem to solve.

II. Generating "yes" and "no" questions. The inquiry model provided in the software program now suggests that students produce questions that can be answered with a yes or no response. Here are appropriate examples:

- Were the Spaniards' weapons superior to the Aztecs'?
- Is it possible that there were fewer Aztecs than originally thought?
- Did religious beliefs affect the outcome?
- Were Aztecs afraid of armored-Spaniards on horseback?

- Did Spaniards bring some type of disease?
- Did Spaniards have a superior form of warfare?

III. Data Gathering. Students use the computer system, plus other references, to answer their "yes or no" questions. At the end of this step, they are closer to hypothesizing causes of the discrepant event. Students are not left on their own to wander aimlessly about hyperspace in search of answers. The system contains guides to offer suggestions about the most likely place to search; there is also a "Journal" for record keeping.

IV. Hypothesis generation. Students are now in a position to generate a hypothesis or hypotheses. In this particular case, their hypothesis might take this form: Cortéz was extremely lucky, he took advantage of Aztecs' superstitions and religious beliefs which indicated he and his men were gods. He was fortunate to find Donna Marina, a native who quickly learned the Spanish language. Cortéz also enlisted the aid of thousands of local Indians who were glad to find a way to overthrow Montezuma. The Spaniards' weapons were especially effective against the Aztecs who were not used to "total warfare." The Aztecs suffered grievously from diseases brought by Spaniards. And last, the city of Tenochtitlán was easy to blockade and starve into submission.

V. Metacognition. Following the problem-solving model, students now evaluate their problem-solving strategies. Bruce and Bruce (1992) suggest that developing evaluative skills improves thinking and questioning during future problem-solving situations — hence, providing for skill transfer. Here is a list of appropriate evaluative questions provided by Fontana, White and Cates (1992, p. 12):

- Is your data relevant or necessary to proving or disproving the hypothesis?
- Do you have sufficient data?
- What is the source of each piece of data? Is the source credible? Is it reliable?
- Does any piece of data incorporate bias or narrow points of view?
- Does each piece of data make a persuasive and logical argument?

- Are stereotypes represented?

Chapter Summary

Metacognitive aids and strategies, introduced in Chapter 2, were elaborated upon by introducing an inquiry-based problem-solving model. This model begins with a discrepant event, then offers students detailed instructions for gathering data, forming and supporting a hypothesis. The last step in the model emphasizes self evaluation to develop thinking and questioning skills in future scenarios.

While the metacognitive strategies received the bulk of the discussion, a teacher's role in teacher-student interactions as described by Newman, Griffin, and Cole (1989) is important. The teacher, as the expert, enters into an interaction with the students; and knowledge, according to Newman et al. is created in the interaction. Inclusion of this concept is not meant to overshadow the problem-based model, but to add to the "functional system" that exists in the classroom.

Last, from a macro viewpoint, we want to create an environment congruent with Bruner's (1963) concepts. These involve presentation of material that is simultaneously exciting and evokes curiosity needed to pursue incongruous situations. Bruner advocates "development of an attitude toward learning and inquiry, toward guessing and hunches, and toward the possibility of solving problems on one's own" (p. 84). He opines that a sense of excitement about discovery is an important ingredient. He states that discovery should provide for: "regularities of previously unrecognized relations and similarities between ideas, with a resulting sense of self-confidence of one's own abilities" (p. 84).

Chapter 4

System Design

Overview

The domain for the prototype is ancient Mesoamerican civilizations. The original focus was the Aztec Empire. As the project developed however, the data base expanded to include brief references to other peoples such as the Mayas, Incas, and Olmecs.

There were many reasons for picking the Mesoamerican theme. First, this culture was excellent for a seventh grade social studies class. Because most information about the Mesoamericans is post-Colombian, there are a variety of conflicting opinions, interpretations, and thoughts about the subject matter. These result from the Spanish destruction of nearly all pre-Colombian recorded history. What we know about these cultures was recorded by monks and Indian chroniclers after the conquest. This background provided a context-rich environment for higher-order thinking, especially in a social studies class. Second, the entire seventh grade was about to begin viewing the *Second Voyage of the Mimi* tapes. These deal with the Maya; building the prototype around the Mesoamericans was an excellent way to introduce material the class was going to cover after this study. Last, the teacher was particularly fond of this theme, having written papers on the subject and having visited some of the Mesoamerican locations.

The thematic hypermedia data base was developed around people, deities, places, things, and events. Research began with the story of Cortés and the end of the Aztec Empire. It then expanded into the life and practices of Aztecs. Practices included their commerce, relations with neighbors, agriculture, art, architecture, and especially their proclivity for human sacrifice and cannibalism. As the research continued, it seemed natural to provide a background concerning the changing world during the "Age of Exploration" (the 16th century). It also seemed appropriate to expand into the other

Mesoamerican peoples because of the questions concerning the origin of all people native to the Americas.

Interface Issues

The interface was designed for a 12-14 year-old, middle-school student who was a novice computer user. Standard interface design guidelines (Hix & Hartson, 1993) were adopted to accommodate the identified user. First, an attempt was made to keep the design simple and consistent. There were three levels in the hierarchy (See Figure 4-1). Users first saw the Main Menu (Figure 4-2). From the Main Menu, they could choose the "Start" or "Puzzles" buttons. If users were already into a "Puzzle" (a discrepant event), they could elect to choose one of several chapters. Each chapter was topical. For instance, the chapter on Cortés and Montezuma dealt with the landing of Cortés and the subsequent defeat of the Aztecs. The latter was sequential by time because it was logical to trace the Spanish march from the coast to Tenochtitlan. Other chapters were also organized by time, but some simply contained a list of cards (this is a hypermedia term analogous to a page in a book) that dealt with the central theme. An example is "Gods and Human Sacrifice."

Software Hierarchy

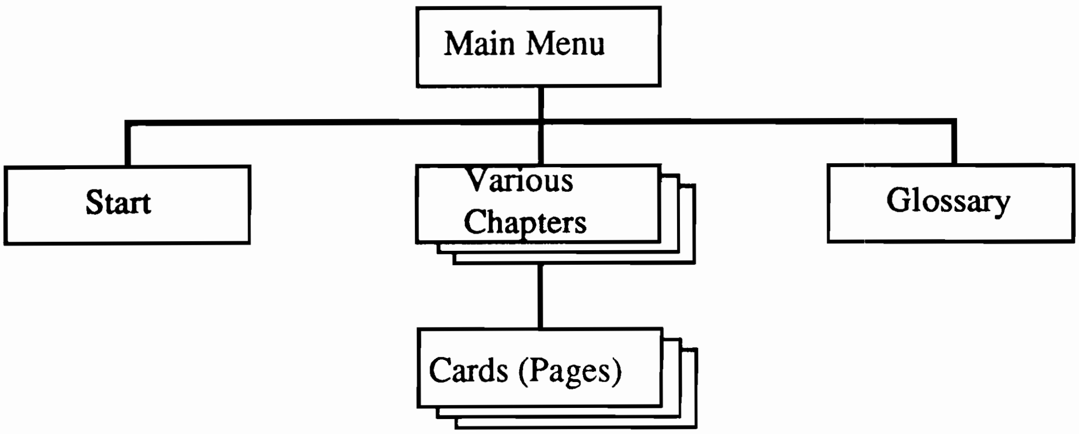

Figure 4-1

The hierarchy was purposely kept to a limited number of levels so that users could quickly develop a conceptual representation of the system for navigational purposes. There were a total of nine buttons available for use at the bottom of each screen. Where a particular feature was unavailable, the button was masked. While nine buttons almost exceeds the proverbial 7 $\pm$ 2 memory slots, many of these buttons were used infrequently. In addition, most were labeled so that users would have little difficulty in determining the buttons' function. A help button was also available to assist users with navigation. All these features were designed to keep users' memory and workload requirements as low as possible.

Figure 4-3 is typical of chapter menus. This example shows the glossary menu, but chapter menus were identical in design. Users could scroll the left column for card titles. Titles of selections were meant to provide some indication of the card's contents.

Main Menu

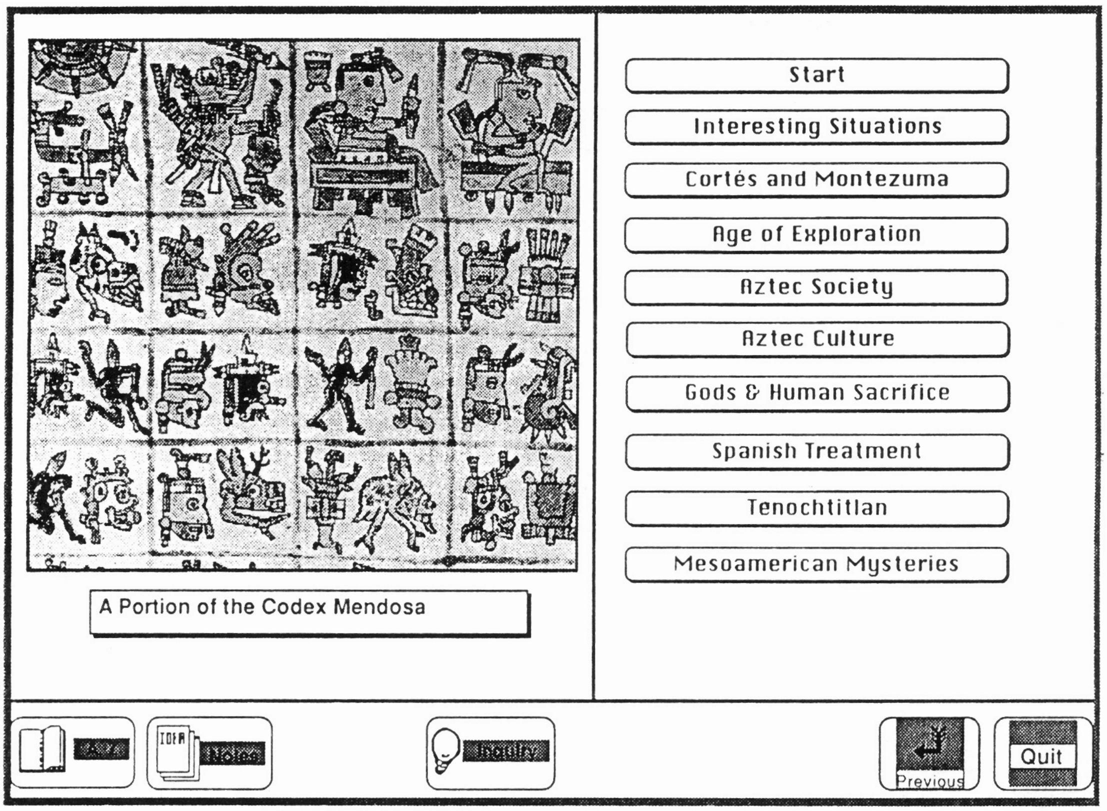

Figure 4-2

Chapter Menu

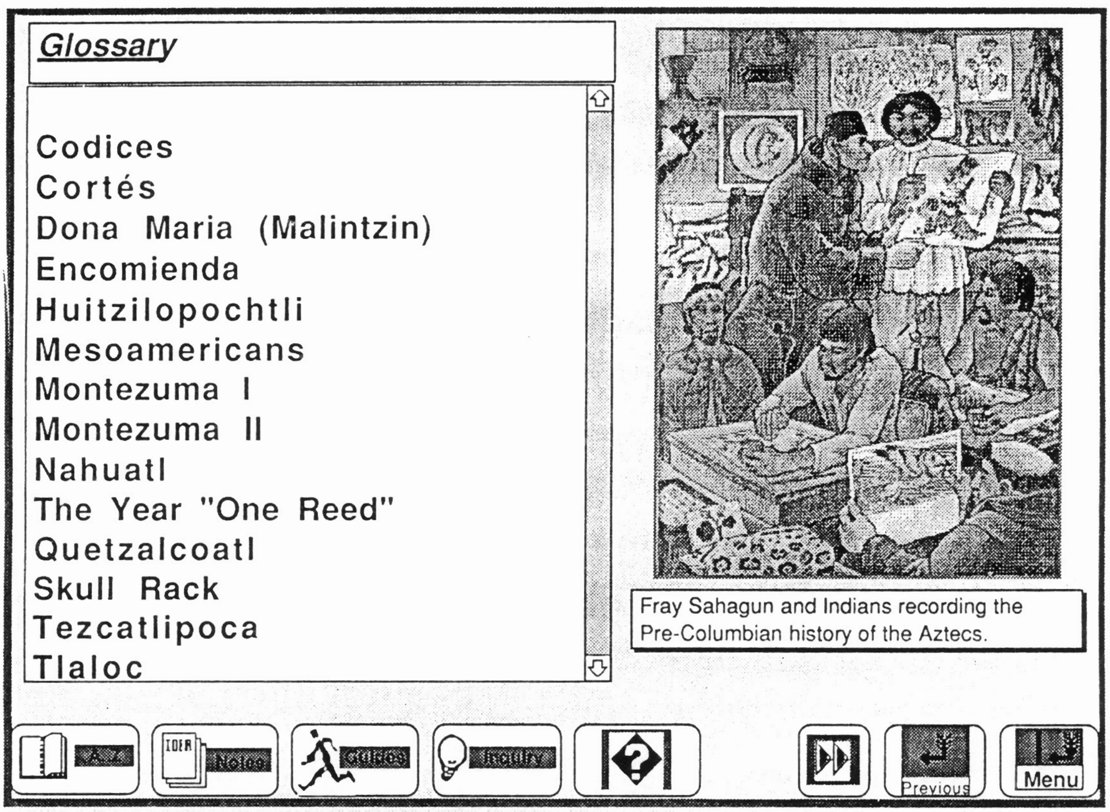

Figure 4-3

Figure 4-4 is an example of an information card. In this case, it comes from the "Gods & Human Sacrifice" chapter. A description of the buttons at the bottom (from left to right) follows:

Glossary: (Marked with a "book icon" and A..Z). The glossary contained those commonly used names, places, events, or things that were common to all chapters. The menu for the glossary is shown at Figure 4-2.

Notes: (Marked with the "pieces of paper" icon). This feature allowed users to keep notes as they perused the data base.

Guides: One of three anthropomorphic guides would appear to offer appropriate choices. The intention was to link users to the most likely selection. In the text of Figure 4-4, readers can see those places that have a guide (hypermedia jump or link) to another location (these places are indicated by the "**See Guides**" prompt). Guides (Figure 4-5) were implemented on a second window.

Inquiry: This button takes the user to information about the problem-solving process. Individual users and small groups would likely find this feature to be of great value. Student groups in this study were supplied with the inquiry model on a piece of paper. The purpose of handing it to them was to provide equal access, and to save time. The lack of a printer with the groups' workstations also dictated providing the inquiry model on hard copy.

Help: Marked with a question mark. The help feature was only available at the chapter menu and card layers. Enhancements to the prototype would include an expansion of the help feature.

Back-one-card: This button allows users to go to the card immediately before the one they are viewing. This is similar to looking at page 35 in a magazine, then

Individual Card

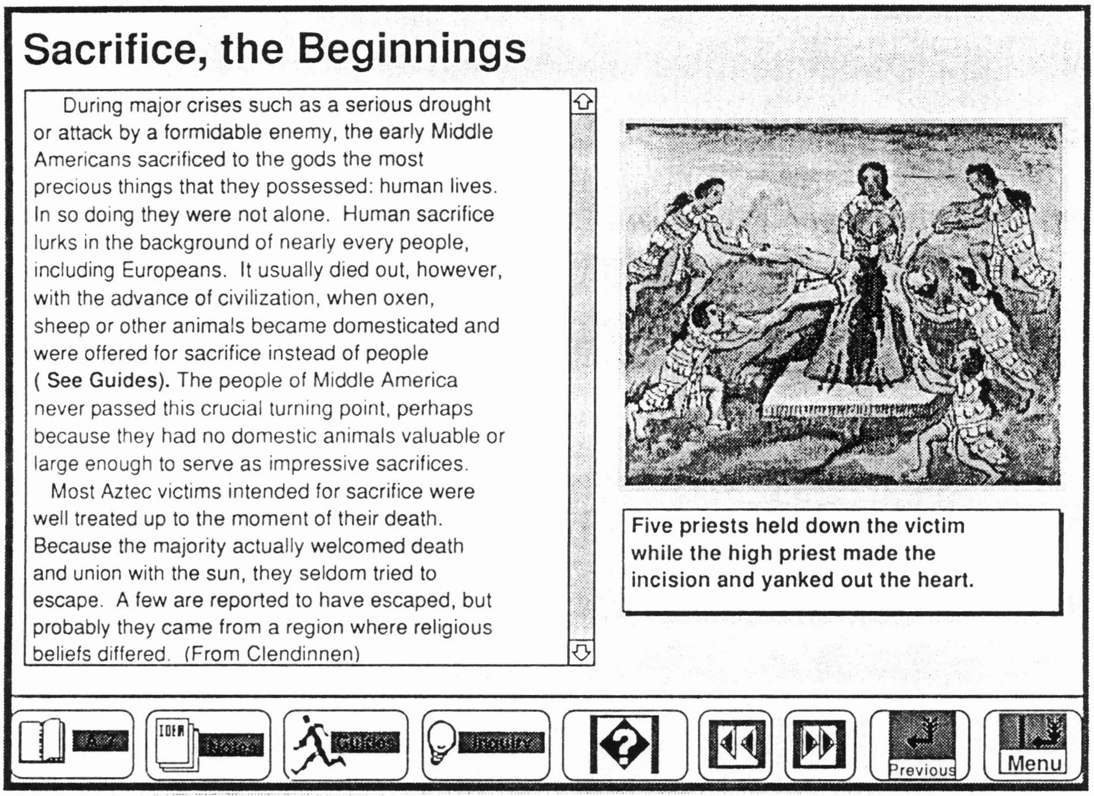

Figure 4-4

flipping back to page 34. This feature was only available in a chapter and could not be used until users were at least up to card number 2.

Next: Same function as the "Back-one-card" button except that users could advance sequentially to the next card in the chapter.

Previous: This was an extremely important button. It provided for the principle of "reversibility" (Hix & Hartson, 1993). It allowed users to return to the card they had just been viewing. The difference between this function and that of the "Back-one-card" button is important. The latter could only be used in a sequence of cards. The "Previous" button could link to anywhere in the program. For example, assume users were on a card in the "Cortés and Montezuma" chapter. They could use a "Guide" to view information about a deity. As soon as the information about the deity was read, users could select the "Previous" button and return directly to the card in the "Cortés and Montezuma" chapter. The importance of this feature is that it saves time, and allows those users who make a mistake to reverse their selection.

Menu: This button always took users to the next level of menus — there were two menu levels . If users were in a chapter, selecting the card takes them to the chapter menu. The next selection would take users to the Main Menu.

Guides

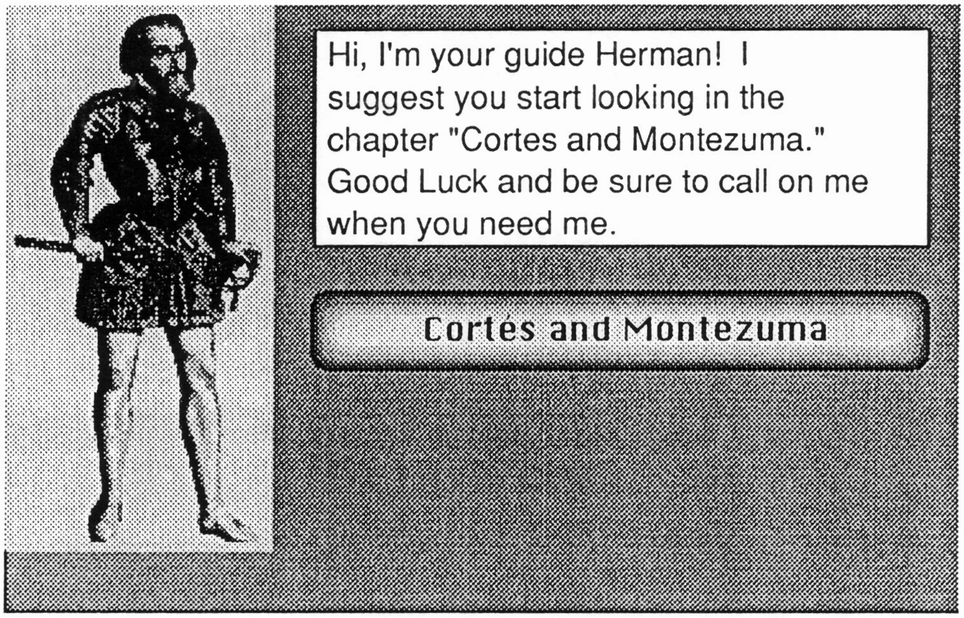

Figure 4-5

Chapter 5

Methodology

Evaluation

This prototype had four goals: (1) to provide information in a specific domain, (2) to support engagement in purposeful, extended lines of thought in which students identify and analyze a problem, identify and relate information necessary to address the task, and evaluate adequacy of conclusions or solutions, (3) to contribute to a capacity for continued learning, and (4) to provide for enjoyment of resolving ambiguous, discrepant, and paradoxical situations. This chapter lays out procedures for monitoring, collecting evidence, and evaluating achievement of these goals. Costa (1991a) states that we cannot use product oriented assessments to assess achievement of process oriented goals. He suggests that norm referenced assessment tools provide only a one-time snap shot of learners. Costa (1991c) states that "in teaching students to think, we are not interested in how many answers students know, we are interested in how they behave when they don't know" (p. 326). Regarding higher-order thinking skills, he says: "Thinking, however is dynamic, we learn from experience, react emotionally to situations, experience power in problem-solving, and are energized by the act of discovery" (Costa, 1991a, p. 313). More appropriately, Costa suggests we use such techniques as direct observation, portfolios of selected student work, interviews, videotapes and writing samples.

Anderson (1991) supports Costa in stating that today's tests support "correct" meanings intended by test makers. He opines that tests have to "challenge learners to discover for themselves what is important, meaningful, and valuable and to create written responses to give evaluators a window on the process of student thinking — to articulate the ways they actually construct meanings from text" (p. 319). Anderson adds to Costa's assessment techniques by suggesting oral presentations, drama, debates, and group collaboration.

The Research Questions

The purpose of this study is to investigate three issues:

1. What are the students' strategies for learning about, and navigating through the data base?

2. Does the discrepant-event inquiry approach provide motivation for sustained exploration of the data base?

3. Do the embedded strategies for problem-solving contribute to higher-order thinking?

Methods

Issue 1. A combination of means was used to record and analyze this question. Software routines were in place to record the sequence, frequency, and duration of selections within the data base. Exercises were also videotaped and audiotaped. Analysis involved following the software audio trail keystroke by keystroke in order to see and make some sense of the navigational trails followed by students. To add to this information, comments from students (based on a questionnaire) and facilitator/evaluators (oral and written) were analyzed.

Issues 2 & 3. Kallick (1991), in discussing higher-order thinking, says that we must create assessment situations that require thinking. These require students to generate knowledge rather than reproduce it. Kallick goes on to state that a critical component for observation of students' products is to explicitly define criteria regarding what constitutes good thinking in a given student.

Means of gathering data consisted of direct observation, videotape, audiotape, post-exercise questionnaires and evaluation of students' products.

Each facilitator/evaluator used the data to evaluate his or her student group's process. A matrix was used by the facilitator/evaluators to record whether or not groups met higher-order thinking objectives. Although ratings were expressed in "Yes or No's", in some cases, it was necessary to identify gradients of success, for example, students often failed at some objective but became better as the week went on. Sometimes only one or two of the groups met an objective. A model by Massialas, Sprague, and Hurst (1975) outlines means of evaluating higher-order inquiry in the classroom Here are objectives provided by Massialas et al.:

Behavioral:

A. Identifying a problem. Based on a situation in which there is a discrepancy in data or knowledge, students question what is meant, what is true, or what information might resolve the discrepancy. The goal is to have them recognize elements in the "Puzzle" that fail to make sense or fit logic.

B. Stating a problem. Students generate an open-ended question based on the discrepant event.

C. Developing appropriate questions. This step involves identifying specific information that may shed light on the problem identified above. Learners are required to investigate cause and effect relationships by formulating "yes" or "no" response questions. The latter required students to develop more organized thinking than open ended questions (Bruce & Bruce, 1992).

D. Collecting relevant data. Students must determine where to locate relevant data, and they must decide whether further information is needed to answer the problem.

E. Analyzing data. Students are expected to break a set of information into its component parts and determine relationships among parts. In analyzing data, students use critical thinking skills to discover underlying assumptions, to distinguish fact from opinion, to determine the relevance of facts, to detect fallacies in arguments, and to discover the ideas of a statement" (Massialas, Sprague, & Hurst, 1975, p. 148).

F. Testing ideas. Given the problem statement and growing evidence, students should be able to discern whether or not their data support, attack, or are irrelevant to the problem being investigated.

G. Developing a hypothesis. Develop a declarative general statement that poses a solution to the initial problem. The statement should reflect students' understanding of relationships in the data.

Affective:

H. Being objective. Investigating issues with an open mind to identify biases in the data. This involves being able to look at alternatives without harboring predetermined conclusions. It also means being able to identify accurate and reliable sources of information.

I. Showing interest. Students are willing to give their attention or have a positive attitude in using the system to resolve discrepant events. Students' attitudes or interest may be observed in some of the following ways: "listening, being excited about something, coming up after class to talk about the issues" (Massialas et al., 1975, p. 149).

J. Showing involvement. Students go beyond the level of just showing interest. They commit themselves to an activity by using their own initiative to participate.

Evaluative:

K. Taking a defensive position. This involves developing a value judgment where students take a defensible position regarding their findings.

L. Grounding a position. Students provide evidence upon which a value position or judgment is based. Students are measured on their ability to provide valid, reliable, and defensible evidence to support a position.

Data Collection and Analysis

Evaluation was formative. Student classroom activity was recorded using audiotape, videotape, direct observation, and software routines. Some written products were also available for analysis. These data were then evaluated and summarized to report on the success of the system in allowing students to learn the subject matter, use the system to access relevant information, and to develop higher-order thinking skills. Facilitator/evaluator notes (Appendix E) were analyzed to compose a picture of the class as a whole.

Instructional Design

Traditionally, instructional design is expressed in a model to solve instructional problems by systematic analysis of learning conditions (Seels & Glasgow, 1990). Frequently used models include the Air Force model, the Dick and Carey model, and the Kemp model (cited in Seels & Glasgow). Seels and Glasgow state that all models commonly involve the following six steps:

- Determining learner needs.
- Determining goals and objectives.
- Constructing assessment procedures.
- Designing and selecting delivery approaches.
- Trying out the instructional systems.
- Installing, maintaining, and evolution of the system through feedback.

The importance of these models in producing instructional systems is acknowledged. Because of the developmental nature of this prototype, however, an iterative design with rapid prototyping will be more appropriate (Brown, 1986). In addition, the influence of the Newman, Griffin, and Cole (1989) writings de-emphasize the hierarchical, reductionist, lower-to-higher structure of traditional instructional design. Operating within the zone of proximal development (ZPD). For example, they state:

> [The traditional] conception has little to say about teacher-child interaction since its premise is that tasks can be sufficiently broken down into component parts that any single step in the sequence can be achieved with a minimum of instruction. Teacherless computerized classrooms running "skill and drill" programs are coherent with this conception of change...In contrast the ZPD conception is concerned with learning a task where the breakdown into components is achieved in the social interaction rather than through a temporal sequence (p. 153).

Participants

The sample for this study consisted of four groups of six, seventh-grade students between the ages of 12 and 13. Selection of students was not random, so results of this study may not generalize to others of the same age and background. The groups were formed by the teacher before arrival of the observers. She gave her class the assignment of dividing into four, equally-balanced six-person groups — without her assistance. She reported that she was impressed by the students' actions in completing this assignment. The results, appeared to be strongly influenced by the groups' composition, while this was unexpected, it was also extremely interesting.

Ability tracking had been discontinued in this particular middle school. The class chosen for this intervention, however, was described by the teacher as consisting of higher ability students. She had chosen this class because she thought there would be the closest match between proposed methods and the personality of the class.

Pilot Test

Three weeks before the actual classroom exercise, a group of four eighth-grade female students tested the prototype. Eighth-grade students were used because of availability. Pilot-test students ran the exercise for two hours. Before the students arrived at the test site, they knew nothing about the nature of the study. Students were given the duties of leader, computer operator, researcher, and recorder (Johnson & Johnson, 1985) — who sat with the computer operator. The following sequence was used:

• The pilot group was briefed concerning the nature of the study, and contributions we expected to obtain from their participation

• The pilot group was given a handout (Appendix A: Problem-solving Handout) about the problem-solving process. The group was encouraged to follow steps on the handout after the reading the "Puzzle." (The "Puzzle was the discrepant event designed to evoke curiosity; Appendix C.)

• One student volunteered to be the leader. Since all of the others reported being comfortable using the computer, the computer operator was chosen at random. She was briefed concerning system usage and navigation while the other three familiarized themselves with the problem-solving model. The computer operator was also shown where to start — to include finding the first "Puzzle".

• After the computer operator was briefed, and the other three were somewhat comfortable with the problem-solving sequence, the four students sat at the computer to begin reading the "Puzzle."

• The pilot group was provided additional textual references to assist with their research (Appendix B: Mesoamerican References). Because the subsequent study was conducted using larger groups (of six), additional resources served several purposes; they: (1) provided additional points-of-view concerning various situations, (2) helped the facilitators compare and contrast the use of the multimedia system with the student's use of additional assets, and (3) gave additional group members gainful activity that would not have been available using only the multimedia system. During the actual study, each group had at least four books or magazines that dealt with the "Puzzle" (Discrepant Event) at hand.

Study Procedures

Due to experience gained with the pilot test, some procedures for the actual study were changed. Only differences are noted:

• During two class periods of the week prior to the study, students were given instruction about the problem-solving sequence. The purpose was to save time, although at the start of the exercise, students appeared to know very little about how to use the problem-solving model. Students knew the identity of the subject matter (i.e., Mesoamerican civilizations), but to the evaluator's knowledge, did not explore this area until the first day of the study.

• We briefed the class about the nature of the study and their participation. It was emphasized that we were not in a hurry for answers; we were more interested in the process. Students were told that their groups were not competing and that groups could conceivably work at different rates throughout the week. Students were also encouraged to try to find relevance between events that happened in the sixteenth century with those of today.

• Each group had its own evaluator/facilitator, who was randomly assigned. Facilitators were doctoral students in Instructional Design and Technology at Virginia Polytechnic Institute and State University.

• The study ran for five days, Monday through Friday. Class sessions were 50 minutes in duration.

• I requested that the teacher provide the name of a strong person in each of the four groups to serve as the first leader. To expedite the study, each evaluator also placed an experienced computer user at the keyboard ("experienced" computer users were self-identified — the self-identified "experienced" users were not always accurate in their analysis but this did not pose a problem).

• Group positions would sometimes be changed throughout the week — at the discretion of the facilitator. We wanted students to gain additional experiences, but when a group was having problems and a change might prove dysfunctional, changes were avoided or delayed. The six positions were: Group leader, computer operator, a recorder to help the operator, two researchers (who used the additional resources), and a recorder who assisted the leader.

• The group was given the problem-solving handout (Appendix A). In order to save time, the students were also provided a hard copy of the first "Puzzle" (Appendix C).

• Because of space constraints, only one video camera was brought into the classroom. The camera was placed with one group each day. Each group had its own audio recorder.

Apparatus

Hypermedia may be developed on a number of platforms. The most common are the Macintosh series and the MS-DOS or Windows machines. While a Windows machine with a 486 processor, a minimum of 8MB of RAM and at least a 100MB hard disc would be sufficient, this prototype was built on a Macintosh IIci. The reason for this choice was the availability of the machine, as well as supporting equipment such as a color scanner, video and audio digitizers. The authoring language of choice was Aldus SuperCard. SuperCard was chosen because of its windowing capabilities. SuperCard also offered a color environment. The developmental Macintosh had 12MB of RAM and a 230MB hard disc; this project could easily be referred to as a "low-end" development. Because of the common availability of the components, this system could be developed by a public school teacher, given enough time and support.

Chapter 6

Data Collection and Analysis

The Groups

Group dynamics played an especially important role in the study, a brief description of each group, its facilitator, and day to day events follows. There were four groups of six students. The decision to have four groups was driven by a lack of space for additional computers. Each group was clustered around a computer in each corner of the room. When classroom teacher and I discussed composition of the groups, it was decided to make groups as equal in ability, as possible. The groups were described by the teacher as close in "potential ability", but perhaps not in "demonstrated ability." This was interpreted to mean that two groups were composed of underachievers. As one might suspect, groups self-arrayed themselves by gender and friendship.

Here is a brief description of each group:

Group 1: A non-competitive female group with one particularly strong, inflexible student. The latter would create quite a challenge for the others to achieve cohesiveness. One female was detached and needed subtle encouragement from the facilitator. I was the facilitator for this group. I have spent most of the past ten years working for the US Army in developing instructional and information systems.

Although each student wanted to use the computer, it became a tool, not the focus of the deliberations. The latter may have been partially a result of the dominant student's disappointment in the computer after the first day — she had expected the computer to tell her the answers instead of having to find them. After establishing an effective working pattern at the end of the second day, the rest of the week went well.

Group 2: This was a very competitive group with five females (close friends) and one male. The latter was, for the most part, excluded from active participation, although he was very attentive and apparently motivated. The facilitator tried to integrate him into the group; perhaps he was intimidated by the five aggressive females. The females wanted to be the first and best. Three female students adapted quickly to their roles; the other two, however, took almost two days to learn their role of researcher. The facilitator was an experienced middle-school teacher in her first year of doctoral studies.

The role of "computer person" was also the most sought after in this group. This group got most of its answers from the computer — as opposed to the additional resources. The group needed less facilitator intervention as the week went on.

Group 3: All males. They could be described as high-achievers who probably would have entered into competition with group 2 had their facilitator let them. This facilitator (perhaps a bit more than the others) kept his students pointed in the right direction to ensure they had a good grasp of the inquiry-based model. The decision to provide more scaffolding to this group, made by this facilitator, is in keeping with methods found in the Newman, Griffin, and Cole (1992) model. This facilitator was an experienced industrial arts teacher in the final month of his doctoral program.

Group 4: All males. These students, like group 1, appeared to start with a bit less motivation than that brought by groups 2 and 3. This group struggled for the first day or two because of individual personalities. In fact, one of the students was particularly troublesome for the group. Unfortunately, this student was also the first leader. The male facilitator was a former high school principal in his first year of doctoral studies.

Research Questions

1. What are the students' strategies for learning about and navigating through the data base?

2. Does the discrepant-event inquiry approach provide motivation for sustained exploration of the data base?

3. Do the embedded strategies for problem-solving contribute to higher-order thinking?

Data Collection

Issue 1. A combination of strategies was used to record and analyze this question. Software routines were in place to record the sequence, frequency, and duration of selections within the data base. The exercises were also videotaped and audiotaped. Questionnaires administered to students on the last day helped clarify their perspective about navigating the data base. The facilitators comments (Appendix E) also supplies information about navigation.

Issues 2 & 3. The following were used in gathering data: questionnaires, direct observation, videotape, audiotape, and students' products. Each facilitator evaluated the student groups' process to determine whether higher-order objectives were being met. In compiling this document, written notes from each facilitator were analyzed and compiled in order to compose an assessment of how the whole class performed (Appendix A).

***Question 1* : What are the students' strategies for learning about and navigating through the data base?**

The phrasing of this question proved troublesome. Identifying a specific strategy, if in fact strategies even existed, was not the focus. The focus was in *how* students navigated the data base. By following the audit trail, then comparing it with the other sources, it was possible to make inferences about whether, and in what manner, students were using the menu system and guides for data base navigation.

The normal sequence of events was for students to obtain their discrepant event, called a "Puzzle" in the software, then set about following the problem-solving steps as outlined in Chapter 3. Students could then navigate the data base for information that would answer their "yes or no" questions and support the hypothesis that resolved their problem statement. The "Puzzles" (discrepant events) were solved in this sequence: (1) how did Cortés defeat Montezuma, (2) why would a captive Indian chieftain volunteer to be sacrificed, and (3) what was the origin of the Mesoamericans? Not all groups progressed at the same rate. One group never got to the third problem, but the emphasis was on the process, not the "correct answer(s)", or rate of progress.

After the exercise, the printed software audit trail was followed on the keyboard, keystroke by keystroke. Although this process was extremely slow, it provided insight into how the students navigated the data base. The software program detailed the keystrokes, duration on a card or chapter, and navigational sequence. This analysis was then compared to the facilitators' oral comments and written notes, and to the videotapes. All steps were necessary because it soon became apparent that the software audit trail, while useful, could provide a misleading picture. A close reading of the audit trail analysis in Appendix F will reveal many instances in which a comment might read: "It appeared the students did not spend enough on the material to read or find answers." For example, Group 2 often spent little time on a page of information — 50 seconds or less. I felt that 50 seconds was too little time to read, ponder the information, take notes, and answer questions. The videotapes, however, clearly showed Group 2 students pointing out information and taking notes as they viewed the computer screen. The facilitators' comments also helped to clarify whether students were aimlessly browsing or actually engaged in deliberate navigation and problem-solving.

Summary of Navigational Techniques::

Analysis of the audit trail (Appendix F) suggested that students needed very little time in becoming familiar with the interface. The trail indicated two primary modes of navigation. The most frequent, and perhaps the most profitable, was in using the menu to select the specific card to visit, then returning to the Main Menu or a lower-level menu by use of the "Return-to-menu" button or by use of the "Previous" button. The second means of navigation chosen by the students was to pick one of the chapters from the Main Menu, then read the entire chapter in a sequential fashion. While this method would be more time consuming, and less efficient, it would also facilitate data base usage for novice users.

Students' Comments About Navigation

Student comments provide insight concerning the interface's ease of use and usability. The following comments are taken from the questionnaire filled out on Day 5:

Did the organization of the ideas on the computer help contribute to your group's problem-solving ability?

Group 1:

"... it was easier to get to the info that we needed."

"Yes, because there were different topics we could use info from."

"Yes, all of the topics that were on the same menu had things to do with each other usually about the same kind of thing."

"Yes, the organization made it easy."

"Yes, we didn't have to hunt for the info. We just looked at the titles."

Group 2:

"Yes, it did, the computer is where we got most of our information."

"Yes — it told us how to pronounce things and gave more ?'s and ideas to work with."

"I thought the guides helped you tremendously. [They] showed you where to go."

Group 3:

"Yes, there was alot of info for each question we asked and it was organized."

"Yes, I was able to follow the guides and solve almost all the Yes and No questions in one period while the people with the books only answered a few."

Group 4:

"Yes, because information was easily accessible."

Did you have any difficulties in finding your way around in the computer program?

Group 1:

"... the computer was easy to use."

"No, because once you know what to do, then you can do it."

"...yes I thought the guide was easy and helpful."

"No, it was very simple to use the computer."

Group 2:

"Yes, they all were a big help especially the guide which helped us if we were stuck on where to look next."

Group 3:

"No, I thought everything was easy to use, and I liked the use of the guides."

"No difficulty, and the guides were extremely helpful."

Group 4:

"The guides were very helpful, [they] gave you an idea, and pointed you to good topics. The computer program was pretty easy to use, and it was interesting."

'The easiest way I saw was just to click on the subject and read."

The preceding comments were listed by group because a close reading of the comments about the audit trail (Appendix F) indicates that each group's activities were different.

Although nearly 99 percent of students' comments were favorable, there were three cautionary remarks. One student reported having difficulty in navigating the data base. Another said the topics were slightly misleading. A third reported that the help screens were not all that helpful. The audit trail indicated the "Guides" buttons got less use than anticipated, but as can be seen in the statements above, some students rated this feature highly. From the literature, frequent usage of this feature was expected, but it did not occur. Reasons for this are in the realm of conjecture. It could be that links to other information were not well designed, or it could simply be that these seventh-grade students were not attuned to working in a hypermedia environment. Other contributing factors may be an unfamiliarity with the system and its interface, or a lack of time. The lack of time was a factor throughout the week; this constraint will be discussed later.

Other features receiving student mention were the scanned images and audio recordings. Students appeared to like the color images. One often heard the students expressing an "Oh, wow!" when the images were flashed on the screen, or when the program used an eye-catching screen transition. When the image was directly related to the text, the image seemed to add considerably to the students' knowledge and understanding. This comment is made based on the judgment of the facilitators in observing the students and their activities in comparing scanned images with the text. The audio was also exceptionally popular with students. Audio recordings were Spanish pronunciations of Aztec deities and cities. Students were often observed playing an Aztec name over and over, then practicing the pronunciation with each other. Students' fascination with the audio may not have supported the problem-solving process or contributed to higher-order thinking, but the audio appeared to support sustained data base exploration.

Question 2. Does the discrepant-event inquiry approach provide motivation for sustained exploration of the data base?

Nearly all indicators, facilitator observations, videotape, audiotape, teacher observations, and student questionnaires, indicated students were motivated and engaged in sustained activity. Students came into the classroom and began work without being told to do so. Work continued until the very last second, then students hurriedly grabbed their belongings (as if they were about to late) and left for the next class.

Students' desire *to know* appeared to be ignited from the discrepant event. Just as the literature indicated, it seemed the discrepant event served as a springboard to sustained activity. One student in the pilot study said the problem-solving sequence was "fun and exciting, just like solving a mystery." This doesn't mean that the problem-solving model was followed to perfection. The students, however, were heavily engaged in the problem-solving process as soon as they received the discrepant event. The facilitator from Group 2 commented that her students were motivated and never lost interest or seemed bored. Behavioral problems did not exist, and the group wanted to get through the problem so they could get into another.

The teacher reported that this whole approach exposed students to new worlds of thought and approaches to learning. In her opinion, the discrepant event approach got the students so involved that they wanted to both continue the exercise, and share notes with each other after this study was over.

Another way of looking at the discrepant event would be under the umbrella of "anchored instruction" or "situated cognition" (Brown, Collins, & Duguid, 1989; CTGV, 1990). Using the discrepant event, students were introduced to a context that had meaning, a purpose, and a direction for engaged activity. As soon as the "Puzzle" was read, students had the context of a specific subject matter domain. Their observed behavior indicated continuous, purposeful pursuit until resolution of the discrepant event. Students then eagerly anticipated, and in fact asked for, permission to engage in the next discrepant event.

In Group 4 there was one exception to the generally excellent use of the discrepant event. The facilitator had a particularly difficult time in getting this group to confront the "Puzzle" and develop a problem statement. This difficulty appeared to arise from the selection of a leader who maintained that he knew the answers and did not need to pursue the matter. Whether the recalcitrant student had a history of being combative, or whether the discrepant event was not challenging enough is unknown. The discrepant events certainly appeared to be challenging and perplexing to the other groups. The teacher did say that Group 4 was composed of particularly strong personalities. This young man's preconceptions evoked thoughts of Gardner's (1991) suggestion that educators have no idea how pervasive and strong are initial conceptions, stereotypes, and scripts that students bring to the classroom. Gardner also maintains these preconceptions are difficult to refashion or eradicate.

With the exception of Group 4's initial difficulty, the students were engaged, motivated, displayed curiosity, and had fun. It would be fair to question, however, whether there were other contributing factors to students' active engagement. For example, the novelty effect may certainly have played some role. This particular section of students may have experienced the "Hawthorne Effect" from being picked to participate in this study. The classroom had been rearranged, and students were told they were part of a study that would probably be written about. Four color computers, four audio recorders, one video recorder, and four facilitators were present to record students' actions. Students were placed into groups and assigned roles (an exception to common practice). They were then given paradoxical statements about people who lived over 400 years ago. These people were known to be fierce and warlike. They sacrificed thousands of individuals at a time and ate some or all of the remains (depending upon whom one believes). The exercise was to last only one week and it was to be presented by methods the students had never seen. Last, the students were probably aware that Mesoamerican Indians were one of their teacher's favorite subjects and that she expected them to think. All of these variables probably contributed to the students' interest and motivation.

These factors notwithstanding, the students were definitely engaged. With the exception of Group 4, the class started work without prompting as soon as they entered the classroom. They appeared to be eager to get started and to pursue information. Students were actively pursuing information, writing and compiling their findings, or briefing the facilitator or teacher. This activity continued until the class period ended. Activity resulting from reading the "Puzzles" suggested that the discrepant event was an important contributing factor in getting and sustaining motivation. The teacher's actions, however, may also be one of the integral variables in the success of an exercise of this type. His or her role will be discussed later.

The data suggested that the discrepant event inquiry model was among the contributing factors to sustained problem-solving activity. Many students appeared to view the reading of the "Puzzles" as the beginning of an adventure.

Question 3. Do embedded strategies for problem-solving contribute to higher-order thinking?

Embedded strategies consisted of prompts and instruction concerning the problem-solving process. As previously stated, students were given these steps on hard copy. Had groups been smaller, and/or systems equipped with a printer, no hand outs would have been necessary.

There are two important issues to settle from analysis of the data. Was there evidence of higher-order thinking and were the embedded strategies the contributing factor — if higher-order thinking occurred?

The second question is addressed first. It may seem that analysis of this question should be deferred, but the data strongly indicated that the embedded strategies *by themselves* were insufficient for these seventh-graders to demonstrate higher-order thinking. This was apparent after the first session. Even though students had the strategies on hard copy and in the computer, the steps were not either not followed, or the process was feeble and lacking in quality. Not one group was able to proceed without facilitator support, scaffolding, and intervention. All facilitators had to actively engage in instructing students how to follow the problem-solving model. Only after the first two sessions were students exhibiting familiarity with the model and proceeding on their own. Having answered the research question very simply by observing that the embedded strategies did not lead to higher-order thinking, it is important to analyze what did happen so we can profit from the results. This is because with the facilitator support, students exhibited evidence of higher-order thinking.

On Day 1, students were briefed, then allowed to begin following steps of the problem-solving process. Indications of higher-order thinking from the Massialas, Sprague, and Hurst (1975) model presented in the Methodology Chapter will be used to discuss the students' performance. Data analyzed to determined whether higher-order thinking occurred came from a variety of sources. The primary source was the facilitators' observations. Immediately before and after each session, facilitators met and discussed the students' progress with the problem-solving model. (Most observations are detailed in Appendices E and F.) When three of four groups met an objective, it was taken as evidence that the class as a whole was able to meet the objective. For example, by day 3, three of four groups could read a discrepant event and formulate a problem statement without facilitator intervention. Students' written products were also used to support the facilitators' observations. The videotapes and audiotapes were useful in helping facilitators recall what the students were doing during the sessions, but because of the noise in the classroom, their value was limited.

Using the Massialas et al. model each facilitator/evaluator provided a rating of whether groups achieved higher-order thinking objectives. Figure 6-1 on the next page shows the results using Yes or No ratings. In retrospect, a scale of zero to four may have been a bit more useful and demonstrative of the groups' achievement levels.

Table 6-1

Facilitator/evaluator Rating Matrix
for Higher-Order Thinking Objectives

	Group 1					Group 2					Group 3					Group 4				
Objectives / Days>	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Perceives a Problem	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y
Develops Pblm. Statement	N	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	Y
Develop Research Quest.	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	Y
Collect Relevant Data	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y
Analyze Data	N	N	N	N	N	N	N	N	N	Y	N	N	Y	Y	Y	N	N	N	N	N
Testing Ideas	N	N	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	N	N	Y
Developing a Hypothesis	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y
Being Objective	N	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y
Showing Interest	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y
Committed & Involved	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y
Defends Position	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y
Grounding a Position	N	Y	N	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	N	N	N	Y
Metacognition	N	N	N	Y	Y	N	N	N	Y	Y	N	N	Y	Y	Y	N	N	N	N	N

The following discussion concerns the class as a whole:

Step 1: Perceives a Problem. In most cases, groups perceived a problem. Discrepant events were phrased in such a way that the information presented was likely to present an anomaly (cognitive dissonance) for students (Appendix C: Discrepant Events).

Step 2: Develops a Problem Statement. This step would be a bit more difficult for students. Not one group could perform this function on the first day. The Group 3 facilitator reported that the group wanted to dive right into the information without any clear idea of what they were looking for or a strategy for narrowing their research. The facilitator reported that students found difficulty in precisely stating the problem. They were used to having a problem statement given to them. Most of the first period would be spent in

articulating what particular problem needed to be resolved, then developing the "Yes" or "No" questions. All groups got much better as the week went on. Their progress was a good sign; the ability to articulate a problem is a task we want

students to be able to perform in everyday situations.

For example, here is the problem statement developed by Group 2: "How did Cortés, with very few men, conquer such a great capitol of Tenochtitlan? Why?

Group 1 asked: "What caused the fall of the Aztecs?" Notice that the phrasing of this question could lead to over-simplified answers.

Step 3: Develop appropriate questions. The Bruce and Bruce (1992) model recommends questions that can be answered with a simple "yes" or "no." These are designed to help students organize their research activities. At first, most students wanted to avoid this step. They wanted to rush off and begin finding solutions. In at least two of the groups, it was as if there were a race to find an answer, correct or not! (While only an opinion, this may be a function of the short, fifty minute classes the students were accustomed to.

The teacher opined that we needed at least one hour sessions.) The purpose of the requirement to develop yes or no questions was to get students to be very specific. Being specific precludes early posing of theoretical questions that would be more difficult to answer. Two groups had excellent questions (up to 24 in one case). The students had initial difficulty, however, in posing these questions; a good deal of facilitating took place to get better questions. Below is the list initially developed by group 2. Notice that there are many questions requiring more than a yes or no. The facilitator had the students rephrase the questions.

Why did Cortés go? What did he want?

How did the Spanish treat the defeated Aztecs?

Why did Montezuma die? How? Small Pox?

Why did Cortés want to destroy the Aztecs?

Who took over the capitol city?

How long did it take for Cortés to reach the Yucatan peninsula?

Was Montezuma a harsh ruler?

How did it come that the Aztecs dominated Central Mexico?

Were many Aztecs killed?

What percentage of the 50,000 Aztec warriors in Tenochtitlan were decreased by death?

Step 4: Collect relevant data. An analysis of students' written products demonstrated they were gathering relevant information. Their writings were directly related to the groups' problem statements. Students close in proximity to the computer, however, appeared to have an advantage in gathering pertinent information. This makes sense because the "Puzzles" (discrepant events) had been developed around information contained in the data base. Here are typical student experiences:

The first computer operator in Group 1 was expecting answers to be given to her by the program. On Day 1, most students stood and watched her navigate the data base. She did not expect to have to search for answers. She left the computer after that session (the plan was to rotate operators in this group; although the group now placed more emphasis on books, the others still wanted to use the computer. On day two, the facilitator went over the duties of each group member and the problem-solving scenario to insure each knew her role. It was apparent that if one was not a leader or computer operator, the students were not sure of their role and may not have been as effective in contributing to the group's mission.

The facilitator in Group 2 reported that student researchers using the additional resources (books) were not as motivated and were much slower to find answers than those on the computer. Videotapes of this group also showed that three students were clustered around the computer — the others appeared to be trying to make some sense of what the additional resources could reveal.

Step 5: Analyzing Data. In this step students break the information into its component parts and determine relationships among the parts. This step was troublesome for the students; they were generally unsuccessful — perhaps needing more teacher facilitation to succeed with. In short, at the end of the study, students needed more practice or guidance in analyzing data. This may have been the first time the students were given information in which quite a few of the facts, claims, and opinions were conflicting. (A contributing factor to the conflicting claims was the 16th Century Spanish destruction of the Mesoamerican written history!) Students had trouble realizing that there were many variables contributing to discrepant events, and that there may be new meanings to the term "correct answer." In Group 1, students found two books that gave the same answer. Even though the computer operators found two theories which contradicted the books' theory, the group stuck steadfastly to answers found in the books, ignoring the contradictions.

Step 6: Testing ideas. Here students evaluate the growing information to see if it supports or is relevant to the problem under consideration. Groups were fair at this task. There were occasions in which groups did not re-evaluate their "Yes or No" questions to see whether they were appropriate. As noted in step 5, students often developed information that was crucial, but they failed to realize its significance.

Step 7: Developing a Hypothesis. Students were fairly good at this step, especially since they were trying to develop a hypothesis as soon as they read the discrepant event. Here is the short paragraph written by Group 2 to explain the first discrepant event.

> Cortés and the Spanish were hungry for gold, jewels and riches. Tenochtitlan had all of these attractions. Many of Montezuma's men died because their bodies were prone to diseases the Spaniards brought over. Also, the Aztec were equipped with many great weapons such as a propelled dart. Because of these weapons the Spaniards were terrified of them, but were so greedy that they overcame this fear. The Aztec were a bit shocked at first of the Spaniard's weapons which they had never seen but also overcame that shock. So we conclude that the Aztec were great warriors but not even their greatest weapons could fight off the Spaniards' terrible diseases. (Unknown Student, 1993).

For those familiar with the Conquest of Mesoamerica, this answer is narrowly focused and somewhat inaccurate. Had there been time, or had the study incorporated class presentations, more theories may have surfaced, leading to a better understanding of the events influencing the Aztecs' downfall. The other groups were successful in uncovering additional information concerning Cortés and Montezuma, but there was always room for improvement on the amount and types of information found by students.

Step 8: Being objective. Students dug deeply enough to find conflicting information. This troubled them at first, but they accepted the explanation that this is not a black and white world. The data base contained conflicting information and different points of view on the same events, but the available class time did not provide the opportunity to become acquainted with the conflicts or to explore them in depth.

Step 9: Showing Interest. Did the students give their attention or have a positive attitude during the exercise? Were they listening, becoming excited or coming up after class to talk about the issues? Students came early and stayed late. There were no behavioral problems and pursuit of the problem-solving steps was evidenced by activity in the classroom. The Group 2 facilitator reported that her group was so proud of their work that they asked over and over if they could share their results with the others. All groups were showing interest (with the exception of one young man in group 4).

Step 10: Stays committed and involved. Did students continue their involvement after class? The teacher reported that the students were just "full of themselves" (Appendix D). By this, she appeared to mean that the students were fully absorbed in the puzzling situation and wanted to keep working at refining their hypotheses. She said they bounced ideas off of each other outside of class. During the week after the exercise, they still wanted to share information with the rest of the class.

Step 11: Taking a defensive position. Did students develop a value judgment regarding their findings? Yes. Each group adopted a position that was in some cases carefully explained to their teacher. Facilitators asked for and received the a carefully worded hypothesis to explain events in the discrepant event. While the positions were not always accurate, as in the one shared in Step 7, each group came up with a position.

Step 12.: Grounding a position. Were the positions supported? The teacher was particularly impressed with the position taken by Groups 2 and 3. She spent a fair amount of time in listening to students explain their positions, then defend them. All groups wrote supporting information for their positions, then shared their criteria with the facilitator or teacher.

Step 13: Metacognition. Did students evaluate their problem-solving strategies? This step was foreign to the groups; only on occasion and in a limited respect could groups perform this objective. When each group got to this stage, students were usually anxious to get on with the next discrepant event. Facilitators had to lead students through a self-evaluative stage in which the facilitators asked leading questions about the relevance, sufficiency, and credibility of material.

In using the Massialas, Sprague, and Hurst (1975) model to analyze students' progress, the facilitators opined that in many cases students were engaged in aspects of higher-order thinking. As introduced above, the strategies in the interface were not useful by themselves. It appeared that they produced aspects of higher-order thinking only because facilitators entered into an interaction with students. Facilitators assessed students' ability level in using the model, then provided scaffolding to the point that students soon started to performing the actions on their own. This process demonstrates the significance of teacher-student interactions as discussed in the section about the "Teacher-Student Interactions" (page 20).

The facilitator of Group 3 made an interesting observation about the methodology and the students' perceptions of the week's activities:

> When asked how they would have studied about the Aztecs had we not been there, their reply was that they would have read the chapter in the book and had little opportunity to discuss events as a group. Interestingly, one member made the comment that the class would not have been exposed to so many points of view were it not for the application and the supporting reference materials. This would seem to indicate that students enjoy researching other materials, text, or otherwise, and that they are not completely satisfied with only being presented the material (traditional approach), especially when it comes from only one perspective (Appendix E).

The data indicates the embedded strategies were insufficient to contribute to higher-order thinking. It was only when coupled with active intervention from the facilitators that the embedded strategies were of value. The problem-based environment seemed foreign to the students. Providing an introduction to the problem-solving scenario the week before was fortuitous. Students appeared, however, to be accustomed to being given the problem statement or being involved in finding the correct answer. To be given a nebulous situation that involved determining the problem, then researching for information among a host of conflicting resources was somewhat of a discrepant event in itself. Initially, facilitators did **not** provide coaching or information to see how students would perform. Results indicated students needed more than strategies on a piece of paper. They could read and indicate they understood the instructions, but their experience with an activity of this sort was limited.

Newman, Griffin, and Cole (1989) might suggest that students did not understand the goal of using the problem -solving process to solve a problem. Based on theories of Newman, et al. it may be that students were not doing poorly, but they were not doing the task at all. Newman et al. say that for students to learn, the facilitator will have to insure that "the task itself occurs in the interaction between the expert and novice" (p. 55). Initial failure of the students to perform well, prompted facilitators to provide feedback at the start of the second session. Scaffolding continued until students could work independently. Newman et al. described a similar situation in their studies: "...teaching the procedure in a Vygotskian manner introduced the children to the task in such a way that the goal *and* the procedure were simultaneously internalized in the course of the interaction" (p. 55).

As the week progressed, students learned the steps and began to apply them. It would have been to our benefit to extend the study into the second week to seek how comfortable the groups would become with problem-solving. Embedding problem-solving strategies within the instruction appears to be facilitative of higher-order thinking *if* (1) the teacher encourages the activity, and continues to prompt, coach, and provide feedback, and (2) these steps are commonly practiced.

Related Issues

Collaborative Setting: The groups were divided into six students each due to constraints already noted. Confusion and difficulties experienced by group leaders suggested that groups of three to four would have been more manageable. This figure is in keeping with suggestions from Johnson and Johnson (1985). The working areas in the classroom were extremely cramped and the noise level made it difficult to communicate. The Group 2 facilitator reported that only two or three students could view the computer screen at one time. Another important factor calling for smaller groups was that the students were not experienced with roles called for in the study. If a group was blessed with a strong leader, effectiveness and efficiency were quicker to appear. On the other hand, when a weak person became leader, he or she may have been too overwhelmed by both the novel problem-solving scenario, plus the responsibility of directing five people through a successful process of answering a problem. Students became decidedly better as the week progressed, but smaller groups may have speeded up the improvement.

Assigning roles to students was crucial. Had we assigned only the role of leader, chaos might have reigned. In retrospect, it would have been useful to go for all groups to go over the duties of each role on days 2 and 3, instead of just days 1 and 2. The roles of computer operator and leader appeared to carry much prestige. If students did not receive these roles, they appeared to be visibly disappointed. Had facilitators emphasized importance of researcher and recorder roles, better results may have ensued.

Time: This was a study of a prototype software system and an inquiry-based approach to setting up a learning environment. The study appeared to be constrained by the amount of available classroom time. In fairness, it was fortunate that the teacher and an extant class in a public school setting was available. It would have helped our study to see whether the success and growth toward higher-order thinking experienced during this week would have continued during an additional week. The classroom teacher was in complete agreement with this comment. See Appendix D for her comments.

Effect of Multimedia: Students seemed particularly impressed by the scanned images. It was the Group 2 facilitator's opinion that context-related images contributed directly to student learning. She said pictures helped place students into context and helped elaborate and amplify the textual information. The digitized audio was also popular. Students would play the voices over and over to hear the pronunciation. This may say a great deal about the effect of multimedia in sustaining student interest.

Another significant point about multimedia arose during the pilot study. We had asked these students to give the facilitators a briefing about their findings. As they were preparing for this briefing, the students were flipping through the chapter on Cortés and Montezuma and using the color pictures as a frame of reference for their presentation. They were using the pictures both as a mental aid, and as a means of making the presentation. The students had not been prompted to present in this manner, but its significance should not be underestimated.

Chapter 7

Conclusions

In the introduction to their book, Newman, Griffin, and Cole (1989) paint this picture:

> A group of fourth graders are sitting around a table working with their teacher on division problems. The teacher puts a problem on the board and the children work out each step as the teacher writes out the developing solution. Turns are taken by the children; murmurs and eagerly raised hands signal group participation. The teacher asks questions, probes here and there, and fills in a little bit, managing to get each of the practice problems on the board . Something new is being constructed which we can see in the way the children begin to respond and in the way that the teacher works with their answers as the lesson progresses. Cognitive change — change in thinking and knowing — is clearly taking place as part of the instructional interaction...(p. 1)

This above scenario is somewhat analogous to aspects of this study. This project began with questions concerning the integration of a thematic hypermedia data base into a seventh-grade classroom. As the software prototype was about to undergo pilot testing, it became clear that the real focus had shifted from those based on technology to those concerning the whole environment. That is, what is the role of the teacher and the students? What is the role of a hypermedia data base, does it transform the classroom, or vice versa? And last, what methods can be used to implement learning designed to instill problem-solving skills in seventh-graders?

It became clear that the writings of Newman, Griffin, and Cole (1989) offer a way of putting the matter into context. In the paragraph above, they focus on the interaction between the teacher and the students. Newman et al. hold that cognitive change occurs in systems of social activity within the zone of proximal development. They label the entire environment a "functional system" in which the exchange between the expert and the novices results in students being engendered with evidence of <u>new sets of understandings</u>.

These understandings are reached through democratically-oriented negotiations (Garrison, 1993) that allow the students to "appropriate" the new information. Technology in this context is a tool or artifact. It simply is one of the integral elements in the functional system; it too is transformed and takes on new meanings from the classroom interaction.

Initial Results

A classroom environment was created that provided for cooperative-student groups to resolve a paradoxical situation through an inquiry based problem-solving model. Students used an approach that allowed them to develop and solve a problem through researching, questioning, and hypothesizing. A hypermedia data base was developed for their research; we made available a myriad of books and magazines to augment the learning environment (Appendix B). Analysis of the data suggests that a primary key to the students' growth came through interaction between students and facilitator(s).

Throughout the exercise, students appeared interested, motivated, and hard working. Their comments on a post-exercise questionnaire consisting of eleven questions were extremely favorable. Just as important were the comments of the teacher (Appendix D). She called the study an unequivocal success; she was very impressed with the software. Last, she said the learning experience was valuable for the children. She felt future students would benefit from the same, or even a longer exposure to this environment.

The Vision

Initially, we wanted to support the teacher's desire for lessons about Mesoamerican Indians. Her primary goal was to foster an environment facilitative of problem-solving and higher-order thinking. The initial concept focused on the hypermedia data base as the central component in the learning environment. The data base was theoretically designed to contribute to metacognition, to reduce cognitive load and to assist in navigation through good interface design.

Interface Design: The interface was designed to be simple, consistent, and easy to use. Menus were listed by people, gods, places, and events. Menus also included metacognitive aids to assist in higher-order thinking and problem-solving. For a novice or low-domain learner, the interface was meant to provide useful assistance in answering: "what should I look at next", or "what is my best choice?" This assistance entailed the inclusion of three anthropomorphic characters to provide information concerning navigational decisions. We envisioned that the guides would receive a fair amount of use.

Higher-order thinking and problem-solving: We wanted students to develop problem statements, conduct research, then form a hypothesis and support it. As discussed in Chapter III, Prawat (1991) suggests that the most prominent technique of teaching thinking skills is to embed the skills into the curriculum — or within the context of specific subject matter domains. The data base was programmed to provide not only information about the problem-solving process, but information that would lead to higher-order thinking and metacognition.

Discrepant event inquiry: One of the research questions specifically addressed the question of whether a paradoxical situation would provide for sustained exploration of the data base. The literature suggested that the introduction of this event would evoke cognitive dissonance and the curiosity to support resolution of the dissonance (Festinger, 1957).

Metacognition: The embedded problem-solving model was meant to provide metacognitive support. Osman and Hannifin (1992) suggested that learners given detailed information about when and how to use a strategy will use it toward successful performance.

Reality

The study began on Monday with an air of anticipation and expectation. Students had been introduced to the problem-solving model during two class periods in the previous week. They were given a brief introduction, then immersed in the discrepant-event inquiry model as outlined in Chapter III. A good deal of that first period was spent by the students in trying to follow the model. At the same time, they were wrestling with the hypermedia data base and sorting through the myriad of books. One could tell from the noise level that a great deal of student-to-student interaction was taking place. The facilitators soon noticed, however, that the students' usage of the problem-solving process needed more than a little fine tuning. As mentioned in the previous chapter, one interpretation was that students were not failing the task, they simply were not doing it (Newman, Griffin, & Cole, 1989). It was outside their realm of experience.

For a part of Day 1, and the beginning of Day 2, the facilitators crossed the line between facilitator/evaluator to become teachers. How can we account for this? Does this situation not throw doubt on the reliability and credibility on the study. Not at all, in fact it reinforces the theories of Newman et al. Once the facilitators could evaluate the students' initial ability, scaffolding could be provided to allow growth. This is analogous to what Newman et al. define as the lower edge of the zone of proximal development. Students were certainly capable, but they appeared to be immersed in methods that were revolutionary to them. They were being asked to not only solve problems, but to decide what problem to solve! The facilitators withdrew from the students long enough to dynamically assess progress (or a lack of progress), then began teacher-student interactions that allowed students to proceed. After Day 1, each facilitator could have told his or her student group : "all right, now I know where you are, let me provide some assistance to help you get where you are going!" After a period or two of assistance, the students began to appropriate the coaching of the facilitators and moved toward independence. Of course this study did not have the luxury of staying in the classroom long enough to determine to what degree, if at all, independence or transfer would occur.

One lesson to the researchers was that initial focus on the hypermedia data base was naive and misplaced. It was almost as if we had gotten caught up in the hype we were trying to avoid. (The hype may be a function of the high costs of technology, e.g. time, money, and personnel.) What we found was that the learning environment was so complex that the hypermedia data base could only play the role of an integral component, not the role of the primary component. It appeared, however, that there was a primary component; it was the interaction between the students and the teacher(s). The hypermedia data base with its metacognitive aids, content, guides, and colorful, facilitative interface provided a valuable tool for the student groups. The data base, however, could not assess the students' level of competence (which differed for every student group and computer operator). It could not make immediate decisions about how to help the students move toward autonomy, and perhaps most importantly, it did not have an established history with each student that would allow the individualized guidance and support he or she deserved.

Hypermedia Development: I designed, developed, and implemented the hypermedia data base alone. On one hand it was an example of the capability provided by today's technology. True, it was a low-end development that included text, color images, and audio. It could easily be expanded to include full motion video. The prototype demonstrated that with the use of a color scanner and a prototyping tool such as HyperCard or SuperCard, the average teacher, with a bit of persistence, can develop tools for the classroom. On the other hand, most teachers are constrained by time. Instead of the concentrated months of development this data base entailed, it is likely that at least two years would be necessary for a teacher working independently.

Not only did development entail spanning the whole instructional and software design cycles, but it was necessary to become proficient in the content area. While this was all quite rewarding, it was also less than efficient and extremely time consuming. A team approach would have been much wiser, saving time and effort--it would most likely result in a much better product. Of course a team was not available, nor is it likely for a teacher to have one. It may be far better for the teacher to use an off-the-shelf hypermedia package. This would allow him or her to concentrate on more important matters, such as methods and interactions with students.

Problem Solving: As discussed in the previous chapter, the students did use the embedded strategies provided for problem-solving. This usage, however, came about only after a great deal of facililtation. Had this assistance not been available , it is likely the students' problem-solving processes would have been of little value. After a tenuous start, they began to pick up the steps involved in the problem-solving process and completed many indicators of higher-order thinking as outlined by Massialas, Sprague, & Hurst (1975). The limited success we experienced may have indicated that if we want our students to solve problems and engage in higher-order thinking, we will have to create opportunities for them to practice, to make mistakes, and to gain in experience.

Discrepant Event Inquiry: In the opinion of the facilitators and the teacher, student groups were engaged, interested, and motivated. A myriad of literature (See Chapter 3) suggested that discrepant events would provide positive results. The data gathered in this study seemed to support the literature. Using the discrepant event or paradoxical situation appears to be a good way to engage students in activity, especially in a problem-solving scenario. It is fair to state, however, that there may be a number of competing factors that contributed to sustained activity. Looking at this exercise from a systemic point of view, we can state that the scenario created for these students appeared to keep them actively involved. Although specific contributing factors were difficult to identify, the facilitators and the teacher were encouraged by the results in using the discrepant event inquiry model, but generalizating the success in this study to other classrooms and situations would be inappropriate.

Interface Design: The design remained simple and consistent. Students' comments about its use were mostly favorable. While the guides were used less than anticipated, we were hopeful that as students work with the data base, they will come to value the guides for their contributions to data gathering and navigation.

Implications for Education

Research and Teaching: To be able to complete this study in a public-school setting with an extant class of seventh graders was fortuitous. The relationship with the teacher had been developed over an 18-month period. We took a great deal of care to ensure the exercise was of value to her goals for this class. Throughout the relationship with the teacher, it was understood that students had to be engaged in meaningful activity that parents, and administrators would expect and approve of. These expectations were met. The point, perhaps is that a spirit of cooperation and mutual need satisfaction is essential; it must be fostered and maintained. Researchers need to nurture and respect the privilege of working in this type of environment.

Problem-solving: One of Perkins's (1986) comments about our poor thinking skills and problem-solving abilities was certainly demonstrated. The students, for example, tended to suggest solutions to a situation before adequately determining the nature of the problem. The computer system was not very helpful in this matter. Low-end computer systems, as used in this study, are not able to evaluate or assess how well the students are following the metacognitive prompts and aids toward problem-solving. This inability points to another role of the teacher — to have and to exercise the decision of when to intervene. This role is particularly important when operating within the zone of proximal development. As Newman, Griffin, and Cole (1989) state: "Instead of giving the children a task and measuring how well they do or how badly they fail, one can give children the task and observe how much and what kind of help they need in order to complete the task successfully" (p. 77).

Metacognition: Osman and Hannifin (1992) suggest that younger learners and novices require more explicit strategies. This may be where we need to look, but we also felt that for these strategies to gain a footing, they need to be implemented over a longer period, perhaps a semester or school year. The automatization of the skills will then have a chance to develop; and near and far transfer can have a chance to develop.

Role of Technology: Based on feedback from the teacher and students, the prototype developed for this study was a well-received tool. The color images and audio appeared to contribute to sustained activity. The prototype was organized so as to quickly provide the type of information the teacher wanted the students to have. Newman, Griffin, and Cole (1989) believe that effective use of technology is in those situations in which it contributes to the zone of proximal development. As such, the computer is a tool, one that can mediate between the teacher and the students. Because this study operated in a social environment, the prototype design did not have to include all of the interactional elements sometimes found in typical CAI. These are contained in teacher-student interactions. This notion is important to developers and designers of classroom software.

The digitized audio and scanned color images were well received. Based on the pilot group's use of color images for briefing purposes, we thought a useful utility would be a routine to put together multimedia presentations.

The Teachers Role: Are teachers going to be relegated to delivering pre-packaged lessons, especially those delivered by technology? This picture is a trap teachers could conceivably fall into if they let themselves. This study reinforces the role of the teacher as the primary agent in successful teacher-student interactions. If anything, the teachers role will become even more important. Newman, Griffin and Cole (1989) state that: "We have seen that the process of instruction cannot be reduced to direct transmission of knowledge, nor are creative learning processes necessarily entirely internal to individuals" (p. 112). Because learning is a two-way process, technology that dispenses information with disregard for the two-way social aspects of the learning situation, will not be able to assume the teacher's role — at least not with the technology commonly available today. Here is a picture of the teacher by Polya (cited in Kinnaman, 1993):

> ...the art of good teaching [is] knowing just when to step in with a question or suggestion, and when to back off and let a student wrestle with a new concept or process. It is an art that cannot be reduced to a formula...Good teachers also have a special ability for recognizing and taking advantage of the *teachable moment*. They understand the delicate balance between stimulating and agitating, between probing and providing, between observing and directing. In addition, good expert teachers know and appreciate the value of their own qualitative assessment of the learning situation and they are able to integrate it seamlessly into their teaching. Perhaps most important, though, the best teachers are able to cultivate in their students a hunger for both academic and intellectual independence...(p. 96).

Future Research

Teacher's Role: The teacher in our study might be referred to by Newman, Griffin, and Cole (1989) as an "observant participant." Her role was to sit with the various groups, to facilitate, and to coach individuals. On three of the five days, she had individual student groups present the results of their problem-solving scenario (the presentations were to her, not to the entire class). These presentations included the problem statement, questions posed during the research, and rationale for the hypothesis.

Having gone through this brief exercise, the teacher indicated she was ready to use these methods in future classes. If we conducted another study with her, the facilitator/evaluators could fade into the background. Should we work with different a teacher, we can now give him or her a better picture of what to expect. He or she could view the videotapes and get a better idea of how the exercise will unfold. We now have a corpus of advice and guidance to provide a different teacher so that he or she could move toward independence in a quicker period of time.

Time: The time available for this exercise was just enough to get good indications of the utility of our methods and usefulness of the software data base. To conduct a study like this in the future, no less than two weeks (10 classroom hours) would suffice. The facilitators felt a longer session would benefit the teacher, but especially the students. It was our opinion that had we gone for two weeks, we would have had time for the individual student groups to present their hypotheses and supporting rationale to the whole class. In fact, some of the students were asking whether they could do so. We felt this would have engendered more excitement concerning the discovery of various types of information. Classroom presentations would also allow the students to be confronted with the variety of conflicting facts, opinions, and conjectures concerning Mesoamerican Indians.

Participants: The extant seventh-grade class used in this study consisted mostly of high-ability students. From the standpoint of generalizability, future studies would profit from a heterogeneous mixture of ability levels. From this heterogeneous class, small groups of three to four students could be composed of equal representation from each ability group. Randomness would be maintained as much as possible.

Content Knowledge: The lessons presented to the students were really two lessons in one. First, they were learning about problem-solving and tools to help them with future problem-solving situations, and second, they were receiving an introduction to Mesoamerican Indians. This introduction would be of value to the class when it studied the Mayan Indians after this study. A host of questions remain concerning what the students learned:

- Did the students learn more about Mesoamerican Indians than they would have in direct instruction?
- If the students learned less about the subject matter in this format, is it possible that they would still retain more, for instance, in a year's time?
- If the students learned less about the subject matter, is it possible that the other skills learned during the study will provide more long-term benefit, e.g., working with groups, problem-solving, and metacognitive skills?
- How do we collect data and analyze these other issues?

Summary

The goal was to create a functional system in a classroom that included a facilitative teacher, energized students, a hypermedia data base dealing with Mesoamerican Indians, additional subject matter resources, and methodology designed to evoke higher-order thinking. In many respects, this goal was reached. Is this the end? No, it is only the beginning. This study has created the potential of encountering a higher degree of success during future exercises. It has also demystified the naiveté we brought concerning the role of technology in the classroom. While the hypermedia data base was well received by the teacher and students, its contribution was that of an integral tool in the learning environment. This study served to highlight the importance of teachers' roles in fostering teacher-student interaction within a functional learning system. Their role is especially important with the proliferation of technology and the challenges it brings to the classroom.

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Appendix A

Problem-Solving

(Note: Most of these examples are adapted from Bruce and Bruce, 1992)

On a daily basis, we encounter many problems. Some of the problems are routine, and we solve them almost immediately. Others, however, may be beyond our experience or knowledge and may leave us curious or even perplexed. In this document, you will find a proven set of problem-solving steps. We want you to use them for this week. We feel that once you become comfortable with these steps, you are likely to find them useful when you encounter future problems. What will you produce after following these steps? We want you to keep notes about each phase; you may also be called upon to present your findings to the entire class.

In the following pages, you will find three things: (1) a short outline of the problem-solving process, (2) a longer explanation of the steps involved in the process, and (3) a classroom example. You may want to read part II first, then use part I only as a quick reference.

I. Outline of the Problem-solving Process

Phase 1: Confronting the "Puzzle."

- Come up with the problem statement.

Phase 2: Generating answers requiring a "yes" or "no" answer

- Ask questions about specific objects and conditions.
- Ask questions to verify the problem.

Phase 3: Gather Data/Evaluate possible theories.

Phase 4: Summarize and develop a single theory.

Phase 5: Self-evaluation of your problem-solving process.

II. Detailed description of the Problem-solving Process

First, you will be presented a "Puzzle" . This problem will come from the computer, or we will read the situation to you. This situation is likely to have some facts, claims, or statements that do not make much sense or fit your "view of the world." That is, your experience and knowledge may not be able to

account for the events in the perplexing situation. Don't worry, life presents us with many situations in which we have to try to solve problems, investigate, or research. The discussion below presents some insight into the steps involved in researching a perplexing situation.

Phase 1. Formulating the Problem Statement. Confront the "Puzzle" presented to you. At this point, your task is to **develop a problem statement** that will guide your research into the Puzzle.

(Note: phases two, three, and four may be conducted at the same time, or the group can move freely from one phase to another. Be sure to record the product of each step as you go through this process.)

hase 2. Come up with **specific questions concerning the problem**. These questions should be answered with a "yes" or "no" answer. Requiring a yes or no answer means that you will be developing a very specific question, not one that is general. This type of questioning also helps you organize your thoughts.

Phase 3. **Gather data, ask questions, form solutions** that explain the problem. This is the phase in which you become a researcher. You have a number of resources available. These include information on the computer, in reference books, from fellow group members, and from resources in the library. You will profit from questioning details related to the "Puzzle." These questions may be about objects, events, conditions, and properties. You may challenge proposed theories, conduct group conferences, and summarize information.

Phase 4. Formulate an explanation. At this point, you summarize and reach the most likely explanation for the problem.

Phase 5. Self-evaluation. At this point, the group analyzes the explanation generated in phase 4. You are going to evaluate the questions you generated, look at the sources you used to support your explanation, and think again about whether the information you found tends to support your explanation. This phase, analyzing problem-solving strategies is essential for improved thinking skills.

III. Example of a Problem-solving Situation (Note: we present only essential portions of a typical group process. Many of the group's questions and the teacher's comments have been omitted.)

Puzzle: Fishermen in the Japan Inland Sea often catch curious-looking crabs. The crabs have strange indentations on the top of their shells. Amazingly, these indentations cause the crabs to appear to have Samurai warriors faces! These Samurai warrior crabs are found only in the Japan Inland Sea.

Phase 1: Formulating the Problem Statement. "Why are the crabs found only in the Japan Inland Sea, and why do they have faces on their shells. How does this happen?"

Phase 2: Phrasing "Yes" and "No" questions. Typical questions generated from the above situation:

- "Are these crabs found only in Japan?"
- "Are there any poisons found in the Inland Sea?"
    - "Are these poisons found in other seas where crabs don't have these faces?"
- "Have there been earthquakes in the Inland Sea?"

- "Didn't the U.S. drop an atomic bomb on Japan during WW II?"

Phase 3: Gather Data/Evaluate possible theories. Reference materials may help generate new ideas. Here are examples:

- Is the Japan Sea as deep as Lake Michigan?"

- It appears that the crabs could not walk from the Inland Sea to other areas of shallow water. Is that true?"

Verifying the "Puzzle" through questions about objects, events, conditions, and properties.

- "Were the fishermen painting the faces on the crabs so they could get money from tourists? (Theory)

- "Can the faces be scraped off the crabs' shells?" (object question)

- "Do I recall that you said the shells had dents that looked like faces?"

- "Are any baby crabs born with the faces?" (object question, the answer is yes!)

- "Then they must be born with the faces?" (property question)

Theory Questions.

- "I bet there must be some kind of help for the crabs with faces so they get to live. Is that true?"

- "Do the fishermen eat the crabs with the faces?" (Answer is no!)

- "Do they throw the crabs back into the sea?

Conducting Conferences. The students gather round to discuss, summarize and organize information discovered so far. All should contribute.

Phase 4: Formulating an explanation. Finally, the students put together the information found during questioning and research. It seems that around 1000 A.D., two groups of samurai warriors fought each other in a huge battle. The Emperor, held to be divine, died at sea during one of the battles. Then, when fishermen found crabs that had random patterns similar to the faces of Samurai warriors, the crabs were thrown back into the water.

Phase 5: Self Evaluation. This phase, the analyzation of problem-solving strategies is essential for improved thinking skills. This process will help you in future problem-solving situations. Here are some useful questions to ask during this process?

- "What questions helped the most in arriving at a tentative answer to the "Perplexing Situation?"
- "Is the data we gathered relevant or necessary to proving or disproving the tentative answer?"
  - "Do we have sufficient data?"
  - "What is the source of each piece of data? Is the source credible? Is it reliable? That is, can we rely upon or trust this source?"
  - "Does any piece of data incorporate bias or narrow points of view?"
  - "Does each piece of data make a persuasive and logical argument?"
  - "Are stereotypes represented?"

Appendix B

Mesoamerican References

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Appendix C

Discrepant Events

(Puzzles)

Problem One: Title: The Good, the Bad, and the Ugly! In 1519, Hernán Cortés, a Spanish sea captain with 550 men (including 32 crossbowmen, and 13 musketeers) and 16 horses landed on the Yucatan Peninsula. This was the land dominated by the Aztec, an empire that stretched from central Mexico to the present boundary of Guatemala. Within this area were 25 million people governed by Montezuma. Montezuma's capital city of Tenochtitlán itself quartered some 50,000 Aztec warriors. Within two years, however, Montezuma would be dead, Tenochtitlán would be in ruins and the empire would be in chaotic disarray. For all intents and purposes, Spanish rule then began.

Where to get started? We suggest you review what you already know about the situation. Next, either look at the hand out you have about problem-solving, or look under "Inquiry" on this computer. Follow the steps. At certain points, the button "Guides" will provide advice.

Problem Two: Here is the story of an enemy chieftain who was to be sacrificed in a kind of gladiatorial contest. He was tied to a stone by a short length of rope, given fake weapons edged with feathers and permitted to fight five fully armed Aztec warriors. When he defeated them all, he was not only freed but offered the command of an Aztec army. He declined the honor, preferring to be sacrificed.

Problem Three: A very curious situation and controversy (that rages to this very day) arose after the discovery of the Mesoamericans. Unlike the nomadic, somewhat "stone age" natives found in North America, the Spanish had discovered very sophisticated cultures in Central and South America. The sophistications included advances in astronomy, medical practices, mathematics, irrigation, agriculture, and manufacturing.

Incredible parallels to the Old World were noticed. Here are a few of the likeness to Old World objects . Mayan art seemed to show pictures of elephants and lotus flowers (neither of which were present in America). Faces on pottery appeared to represent various races, to include: Negroes, Chinese, Semetics, as well as white, bearded men. Temples resembled those of the mid and far east. Cloth making looms were exact duplicates of those found in Egypt. Temples resembled those of Babylon.

Appendix D

Teacher Comments

The following are notes taken during a post-exercise interview with Mrs. Carolyn Cox, the seventh grade social studies teacher in whose classroom the study was conducted. Mrs. Cox is a veteran social studies teacher with over 20 years of experience. Her comments are paraphrased.

Was the exercise of value? The exercise was an unequivocal success. I knew that the content and methodology were both new to the students; they were starting at ground zero. The reason I am so pleased about the results is that the students came so far in such a short time. What is interesting is that the students all profited and grew in different ways. This was a total environment. The important thing is that the students did not just learn content, they learned that there was a whole world of study out there they did not exist before (the Mesoamerican civilizations); they learned that they can be the source instead of the recipients of information; and they learned more about working in a problem-solving group.

On Group Activities: I don't always place the students in groups, so they got to experience the value of learning so much from each other. They also learned not only from each other, but when the group was together, there were much better results from the group interaction. The students would leave the classroom with questions on their mind, then they would bounce ideas off of each other during the day. This led to individual questioning and thinking. It was as if the synergistic effect of the group interaction led to a better product than would have developed individually.

It was interesting to see the ones who are good at book learning. This was a new experience for them. They were put into a new mode for learning. We probably lost some time in group dynamics. That is, the students really spent the first two days in learning how to work with one another. As you know, as a class exercise, I had them divide into four groups. The result was that we had four groups of somewhat close friends. Had we made the groups heterogeneous, it is likely the students would have spent even more time in developing effective working relationships. As it turned out, each of the four groups were different in personality. A complete study could have been done on each of the four groups -- due to the dynamics and interactions.

Let me elaborate on the unique characteristics of each group.

Group 1 had some interesting personality interactions to work out. Who was going to be the chief, and who the followers had to be worked out. They were all very capable, it was just a matter of working out the dynamics.

Group 2 consisted of the over-achieving ladies. They wanted to compete with everyone else, especially the over-achieving boys.

Group 3, the over-achieving boys, sort of sensed that the ladies were trying to beat them, but their facilitator held them in check.

Group 4 consisted of the unemotional boys. They were very blasé about the whole affair. Had they picked up on the fact that the over-achieving girls were out to beat everyone, then this group probably would have picked up steam. It also seemed that we did not have the best match between the facilitator and the group. Perhaps we should have put the female facilitator with these boys, and put the male facilitator with the over-achieving girls. I think then we would have had a better gender and personality match for more effective facilitator-group interaction.

The Software: I loved the software. It was different for the students too. It provided something outside their experience. Both the subject matter and the approach were different from anything they had previously encountered. The content did not overlap into areas they had already studied.

Problem-solving: The problem-solving exercises fit right in with the interdisciplinary approach we try to emphasize during the year. It was similar to the scientific problem-solving that is taught in science class, for example.

Allotted Time: One week was too short. What we got from this week was a verification of the validity of the concepts and methods. We know it works. I would be more than willing to do this again. Two weeks seems about right. The 50 minute classes are another constraint. Due to the shortness of time, you have to introduce the subject matter, get some practice, some closure, and then the students are gone. I feel this study needed a full sixty minutes every day for two weeks.

Discrepant Events: Were the discrepant events working? Were they engaged? Yes! The students were so full of themselves, that they wanted to continue talking about it on the Monday after the exercise. The groups wanted to compare notes, to see what the others had come up with!

Far Transfer: Because of the short study, it will be a while until we will be able to see whether the metacognitive skills will transfer to another situation. The indications showed the potential. The students' confidence levels have increased as a result of this experience. I can see this as we head into the *Second Voyage of the Mimi* exercise. It was good that we handed them the problem-solving steps on paper. Having something in black and white is very useful. This really helped them put the little things, or the building blocks of problem-solving together.

Appendix E

Facilitator/Evaluator Notes

Noes From Facilitator One

Grou 1: A non-competitive female group with one particularly strong, less-than- flexible student. The latter would create quite a challenge for the others to achieve cohesiveness. One female was detached and needed encouragement from the facilitator.

On the first morning, the dominant student volunteered to be the computer operator. Of course she had no idea that she was dealing with a hypermedia design and not a computer-based training program designed to tell her all of the answers. She had no trouble at all in learning how to navigate the data base. The teacher assigned the position of group leader to another student. She was not sure of herself, and was perhaps intimidated by the dominant female; during the first day, the leader kept pretty much in the background. The rest of the group clustered around the computer to see what answers it would divulge. Most of the first day was spent in trying to come up with an acceptable problem statement. By acceptable, I mean that the students had never developed a problem statement and were having trouble developing one that presented an incongruity or anomaly to be resolved. I gave them assistance in coming up with better problem statements and "yes" and "no" questions.

At the beginning of the second day, the group received some needed guidance concerning the problem-solving model and the role of each group member. The dominant student was perhaps disillusioned by the lack of the computer's ability to tell her the answers. She wanted to be the new group leader, but the old leader seemed determined to forge ahead. The latter was allowed to perform as leader until a new "puzzling situation" was encountered. The students were now very systematic and deliberate in their search and in following the problem-solving model. The dominant student became a researcher; all of the others wanted to become the "new" computer user. (The interest in using the computer would be a common theme.) The group members became more absorbed in their respective tasks. Although each student wanted to use the computer, it became a tool, not the focus of the deliberations. The latter may have been partially a result of the dominant student's disappointment in the computer and her interest in what the reference materials would provide.

On days 3 and 4 a new leader and computer operator took over. By now the students had picked up the rudiments of the problem-solving process. They began the puzzle concerning human sacrifice. This particular topic would be followed for two days. The students were diligently researching the problem by using the computer and additional resources. Even though they were going through the right steps, they were quick to find answers to the problem, then
stick to them. This was the case, even though they had also uncovered additional evidence which refuted or at least called into question some of their findings.

Notes From Facilitator Two

Observations are broken into four categories: groupings, the problem-solving process, computer usage, and general observations.

Groupings: According to the classroom teacher, students were allowed to form their own groups. Group 2 impressed me as a group of close friends who are all motivated, high achieving students. The one exception was the boy in the group. Though he seemed to be a motivated high achiever as well, he did not seem to be close to the females. I believe he was added to the group by the teacher after it had formed.

The group worked well throughout the five days, and I observed no group dissension. Three of the six members adapted quickly to their roles. Two females, who were assigned as researchers, took at least a day and a half before they pursued their research whole heartedly. I feel that this had more to do with their not knowing what to look up than a lack of interest on their part. Once they were truly needed by the group, they did their work well.

The male seemed very interested in the assignment, but he did little to contribute. Perhaps this was because he was not in his own peer group, or he was intimidate by a group of five assertive females. When I encouraged him to assist with the research, he became engrossed with readings that may or may not have been relevant to the question at hand. Though the male was not vocal, he was very attentive throughout the five days.

The assignment of roles to group members was an excellent way to divide responsibilities and to keep members on task. The "computer person" was the most sought after role in my group; I feel that the assignments saved us from a few arguments!

The computer operator in my group had limited experience. I was amazed at how well she was able to navigate through the program with little help.

A final word about grouping concerns group size. I realize that there was no way around it in this particular situation, but six members is too many! Only half of the students could see the computer screen or hear other members' questions and comments at any given time. Groups of three or maybe four seem ideal for assignment of this type.

Problem-solving Process: The group got progressively better at coming up with problem statements. They needed a fair amount of prompting with the first problem, some with the second, and none with the third. The same was true with their generating "Yes or No" questions. On the first problem, many questions did not require only yes/no answers, and students had to rewrite them. On the second and third problems, they were checking each other instead of my having to intervene.

In the "gathering data" stage, those students who were on or near the computer did a fantastic job. They were able to navigate, search, and use the guides as necessary. Most of their answers were gotten from the program. Those students using books for research did a fair job. Their comments indicated that it was not as easy or fun to get information from books as compared to the computer. When encouraged by group members or me to find specific answers, they were able to do so. On two occasions, it was a group effort to decide which word to look up in the index. On the final questionnaires, two members of my group indicated a need for more resources.

The group did a very good job with summarizing and developing a single theory. Again, though, it was the three females who worked closely with the computer who had the most input.

The self evaluation phase was generally conducted as a discussion with me leading. The students did not seem to take this part too seriously — as they were always anxious to tackle the next task. At one point, when asked if all gathered data was relevant or necessary, they did strike some irrelevant information from their final summary.

The only problem I observed in my group's problem-solving process was their desire to "beat" the other groups. No matter how much I stressed that we were more interested in the process, they wanted to finish first, and they wanted to do the best job.

Computer Usage: Students were able to find their way around the program easily, and if they did get stuck, they called on the "Guides" or used trial and error. Judging by what I observed from the research done on the computer and research done with books, the students were much more willing to find answers through trial and error on the computer. Those using the books would ask for help if the answers were not found on the first try. One student told me that she liked working with the computer because "Everything is right there for you."

Students seemed particularly impressed with the scanned images in the program. They seemed to add a lot to the students' knowledge and understanding of the various topics presented. My group really enjoyed the sound that was added to the program. It was not unusual to see all six crowded around the computer listening to the pronunciations of a word. It was difficult to hear though, because of all the background noise in the room.

General Observations: What I observed in those five days was six students with a desire to learn more and more about the Mesoamericans and their lifestyle. These students were motivated to learn, they had an interest, and they were on-task. Behavior problems simply did not exist. Even when students did not fulfill their roles perfectly, they never lost interest or seemed bored. The students were always anxious to tackle the next "puzzling situation."

The statements in the above paragraph are not objective observations, but rather are impressions based on objective observations. When I see student who are focused on the task, who ask repeatedly: "When can we start on the next problem", and who come into the classroom and get to work without being asked, I am going to assume that these students are motivated, interested, having fun, and learning something. They were so proud of their work that they asked me over and over if they could share their results with the class. Unfortunately, there was no time to, but I hope the teacher had time later.

This project seemed very worthwhile and beneficial to the students. Judging by the questionnaires, my group tended to agree.

Notes From Facilitator Three

These notes are organized by day by day student activities.

Monday: One of the things I noticed when the roles were being assigned to each group member was the members' perception and inference that certain "jobs" carried more prestige than others. Accordingly, the two most sought after roles were group leader and computer operator. Clearly, the role of researcher and recorder had been under-emphasized, even though the fulfillment of these positions was vital to the group's success or failure in comprehending the events leading to the perplexing situation. I sensed a feeling of disappointment when certain members were not assigned to the role they wanted.

The group also struggled with the problem-solving process in general. As I almost expected, the group wanted to "dive" into the information without having any clear idea of what they were looking for or a strategy for narrowing their research. We had to back up and review the problem-solving process before I could "turn them loose."

Once into the application, the group encountered some difficulty in precisely stating the problem to be solved. They were not used to having to take pieces of the passage and formulating the problem; rather, they were looking for a statement to be given to them. We spent several minutes reviewing what we know from the passage before we were able to define our problem statement. Once the problem was defined and agreed upon by the members, they immediately started proposing solutions to the problem without having performed any research! It was almost as if they perceived the problem-solving process as a race against the clock, that is, it was more important to finish quickly than to engage in quality work.

The group also had problems generating the yes/no questions. The tendency was for them to ask theory questions, and we had to go back and reformulate them into the yes/no questions. Moreover, I noticed that once the group started asking the yes/no questions, they did not go back and review the list to ascertain whether or not the questions would truly contribute to the solution of the problem at hand. Again, I see this attributable to their lack of refined research skills as much as to their inexperience with the overall problem-solving process.

In general, the group did very well once the momentum became established. They seemed to be engaged in their research and were able to articulate exactly the nature of their research. Again, there were moments in which the group leader needed to be reminded to keep his group on task, and the recorders were not always into "recording."

But on the first day of the first shot at this process, I am convinced that we are right on target.

Tuesday: I started the day with a review of the problem-solving process and how that process can be generalized to other problem situations. For example, I discussed how the doctor might use somewhat of a similar process when diagnosing illnesses (Does your throat hurt? Have you lost your appetite? Has this pain persisted for more than 24 hours? etc.) When I quizzed the group about the problem-solving process, they said the first step was to generate the yes/no questions. They had forgotten that the statement of the problem comes first. Furthermore, I had to tease out of them the statement of the problem, even though they had stated it explicitly just the preceding day.

Today's plan was simply to stand back and let the group conduct its research. I intervened only when directly asked to do so. On one occasion, the researchers discovered that there were discrepancies among the texts concerning the precise number of soldiers that accompanied Cortés. It seemed that they were looking for "absolute" answers and had difficulty reconciling the fact that modern day historians have also had to make some guesses about what Aztec life was like. I explained to them that in this instance, a close approximation to the "truth" was as appropriate as the absolute answer.

I did spend a few moments reminding the members of their respective roles and responsibilities, especially the recorders. In addition, old habits die hard, and the group reverted back to asking theory questions rather than concentrating on responding to the yes/no questions. However, once on track, the group seemed to work very diligently.

Obviously, in a collaborative atmosphere, there is a certain amount of socialization that must first transpire before the group becomes cohesive. The group's chemistry and the leader's ability to lead are but two factors that can make or break and educational experience like this. This group was fortunate to have a leader who could lead, and I believe this is evident through the intensity and sincerity with which the group conducted its research.

Wednesday: Today the group came to the conclusion of Problem 1. They spent the first 15 minutes reviewing the data they had collected about the problem, then the teacher came and sat in on the group, discussing their findings for the next 20 to 25 minutes. Interestingly, the group had trouble realizing that there was not **one** simple answer for what happened, but it was a combination of events over time that led to the demise of the Aztecs.

Even though the group was quite successful in answering the yes/no questions, at times the members failed to realize the significance of information that they had unearthed. For example, one yes/n o question generated was, "Did the Aztecs die of foreign diseases?" Even though they were able to document the spreading of such European diseases like smallpox, measles, and tuberculosis to the Aztecs, the members failed to include this fact as part of the explanation for the Spaniards' conquest of the Aztecs.

After the teacher met with the group, I spent some time reviewing the problem-solving process with the members and tried to elicit their thought and feelings about the overall process. They stated that they liked the process and that they felt it was quite useful to them in solving the problem. When asked how they would have studied about the Aztecs had we not been there, their reply was that they would have read the chapter in the book and had little opportunity to discuss the events as a group. Interestingly, one member made the comment that the class would not have been exposed to so many points of view were it not for the application and the supporting reference materials. This would seem to indicate that students enjoy researching other materials, text, or otherwise, and that they are not completely satisfied with only being presented the material (traditional approach), especially when it comes from only one perspective.

Thursday: The group began considering the "puzzle" concerning human sacrifice. The group decided that they wanted to change roles, and so we spent a few minutes deciding who was going to do what. Unfortunately, we encountered some degree of loss of continuity in the problem-solving process as the roles interchanged, perhaps because the "new" group leader was not perceived to be as strong as the first. This is what learning is all about, you put students in new roles and you (the teacher) facilitate their success in that role. It is no wonder there was a break in continuity, the students had never been given the opportunity to be successful researchers, group leaders, and computer operators. In a motivational sense, I suspect this exercise was more exciting and rewarding than many of the educational experiences they had to date.

As the group got underway, the members still needed to be reminded of the problem-solving process. I do not know if this problem was inherently less perplexing to them than the Spaniard's conquest of the Aztecs, however, we did struggle a bit to get a precise statement of the problem. I suspect that they felt like they had covered much of that material as they were researching the facts surrounding problem one. But nonetheless, the subject was right on target (in a motivational sense) for seventh grade boys — the guys were really into the human sacrifice issues.

Disappointingly, the group still had some problems generating relevant yes/no questions that could lead them to proposing a theory about why humans would let themselves be sacrificed. However, I attribute this more to their inexperience with the process than as an indictment of the benefits of such an exercise. We were not looking for perfection, only for a glimmer of hope that with sustained practice, such a process might lead to improved critical thinking skills.

I noticed the guys becoming quite fascinated with the digitized audio. In fact, I could hear them practicing the words on the audio tape. I don't know that this necessarily indicates higher-order thinking skills, however, it does seem to say something about multimedia's ability to provide motivation for sustained exploration of an application.

Friday: To the extent I was able to ascertain, I found they still needed to be reminded about the "big" problem to be solved. Their tendency was to jump right in again and start perusing the data base. However, as I mentioned earlier, I think some of this group's diminished focus on the problem at hand was due partly to the lack of a strong group leader. However, much to my surprise, they did, as a whole, have a pretty good grasp on the idea of human sacrifice and how such rituals had become such a pervasive part of the Aztec culture.

Notes From Facilitator Four

Let me begin by giving some thoughts about my group which I shall call group 4. This group consisted of males; there seemed to be a wide mix of ability levels, ambition, maturity, and interest. The assignment of roles within the group was not good but after three days of observation, I don't think it could have been improved. The group was made up of one very intelligent boy (possibly two), two boys who wanted to goof off, one boy who did not have a good grasp of the English language, and one boy who did not come until Wednesday but seemed to want to take a part in the research.

I began by reviewing the inquiry method of coming up with a problem statement after being presented with a puzzling situation. I then reminded them of the need to generate "yes" or "no" questions, gather data/evaluate possible theories, summarize and develop a single theory, then conduct a self-evaluation of their problem-solving process. It was very difficult to get them to confront the perplexing situation and develop a problem statement. The group leader seemed to have all the answers because he had learned this from Mrs. Cox or some other class he had been in.

Even after developing a problem statement this group did not want to generate "yes" or "no" questions. The group leader did not assign duties to the other group members. They all wanted to see what the computer could do. It was also as if they expected the computer to give them the answers without any effort on their part, as if the answer would jump out at them.

The assigned leader on the first day set the tone and attitude for the group. He seemed to be an intelligent boy but showed a strong refusal to accept suggestions from me. He often frowned when looking at me or in my direction. I noticed that when Mrs. Cox, the classroom teacher, intervened he became very enthusiastic and reacted very favorably toward her. He even allowed her to take the direction for the group. When I tried to do this, he showed a strong determination to be the leader and was reluctant to accept any suggestions for directions from me.

Because there was a reluctance to accept directions, group 4 missed opportunities to capitalize on the information in the books and in the data base on the computer. They jumped all around in the computer program. I constantly tried to guide them in the direction of information to help solve their problem statement. At times, however, it seemed as if they were getting the picture in using the steps in the inquiry problem-solving process.

We have spent four days and barely covered enough information to address the first two issues of Cortés' and Montezuma and Human Sacrifices. I don't think that enough information has been uncovered or at least they have not applied the information in a way which would solve their Puzzles.

Summary of each day's events:

Day 1: Group 4 jumped from question to question. They would not confine their search to one question or ask "yes" or "no" questions. They seemed to lack an understanding of the inquiry method even though they all said that Mrs. Cox had gone over this with them.

The group leader has not exercised control of the group. He has let them do just about what each individual wanted to do.

Day 2: Group 4 stated a problem. They continued to develop "yes" and "no" questions. It looks like they may be getting the picture of the inquiry method. As they answered these questions, more questions were developed and answered. The team leader is still not leading. * **All of the members of Group 4 wanted to get on the computer.***

Day 3: Today they were beginning to ask more questions and putting information together. Students changed positions, one of the boys who had not been participating much ran the computer today. He began to get involved and made quite a few contributions. They still had a problem jumping around. The leader has an attitude that he knows much of the material and doesn't need to research anything. This is hindering the research of the group. He has also not delegated responsibilities very well.

Day 4: The group leaders changed today. I noticed the group leader from the first three days relating well and getting more involved with Mrs. Cox. Today it seemed, however, as if Group 4 lost all momentum. They acted like that they had never seen the inquiry method before.

Day 5: The group leaders changed again today. Today I noticed that the group seems to be using the problem-solving process more than on previous days, as the case should be. They seemed to be expanding their questioning process more. They were raising some questions which were leading them in new directions. There was one boy who did not really get into the exercise. This process does not appeal to all learners.

Three Issues:

1. What are the students' strategies for learning about and navigating through the data base?

I allowed them to pursue their own course on Monday. They jumped all around the data base. They never read the entire text on any aspect. They experimented about navigating through the data base. Because they were jumping all over the place they missed the cues and guides that could have given them direction. On the second day I showed them and told them about the cues and what they might look for; this seemed to help. Since Tuesday they have made more use of the menus, cues, etc. As the week went along this group began to develop some basic problem-solving techniques. The team leaders never did make clear assignment of duties and follow up on these assignments. Even with advice, they seemed reluctant to develop a strategy for navigating through the data base. They explored what seemed to interest them instead of what would help solve the problem.

2. Does the discrepant-event inquiry approach provide motivation for sustained exploration of the data base?

Most of the members of this group seemed to be motivated with this approach in exploring the data base. These students were challenged in their theories and hypotheses. At first they just stated thoughts based on what they thought or were taught previously. They had to be challenged to prove these theories. As they investigated areas of the data base in solving the problem, they were prompted to explore other areas which added information to their problem-solving effort. It took them almost a week to realize the advantages of the data base and how to use it in solving their problem. If these students had more time and more data bases at their disposal, I believe that they would spend a great amount of time exploring such a data base.

3. Do the embedded strategies for problem-solving contribute to higher-order thinking?

I must state at this time, that the students in group 4 were challenged by the problem-solving. The embedded strategies caused them to research material to provide a basis for their thoughts. As the week went along they seemed able to reason out situations based on the information which they had discovered. They were beginning to be able to reason out the why's and how's of solving problems. Instead of yes or no answers to questions, they began to be able to state facts in reasoning out the problems in this exercise.

Appendix F

Audit Trail Evaluation

Group 1

Day 1 Group 1: Most of the first day's computer usage was spent in exploring and getting accustomed to the interface. The first computer operator expected to be led by the computer and to be given the answers. The time the operator stayed on any particular chapter appeared to be too little for the group to have gotten useful information. The user navigated by menu usage.

Day 2, Group 1: The first computer operator was easily talked into taking another role. The student assisting the computer operator on Day 1, now became the operator. Day 2's assistant would be Day 3's operator. This practice would continue throughout the week; this was the only group to change operators this frequently. Day 2's operator quickly learned to navigate. She used the "Guides" button six times. She was also making effective use of the menu selections at the beginning of each chapter, then returning to the menu using the "Previous" button. The content she explored concerned the legends about the "Return of White Gods", and "Spanish Advantages." Both were appropriate to the question under study.

Day 3, Group 1: The group started on the second problem. The operator spent about three minutes in the beginning sections (reading the new "Perplexing Situation"), then she started using the glossary and the chapter on "Human Sacrifices." She spent 24 minutes in the appropriate chapter, going to and from the various cards by using the menu, then returning to the menu by use of the "Previous" button. She used the "Previous" button ten times and the "Guides" button twice.

Day 4, Group 1: The operator navigated primarily by using the menus. There were two uses of the "Guides" buttons. The user had somewhat of a tendency to start at the beginning of a chapter, then use the "Next" button to move through a chapter. She spent six minutes in the chapter on "Human Sacrifices", an appropriate decision. After starting the third problem, concerning the origins of the Mesoamericans, she followed the same pattern — using a combination of "browsing" and making selections from the menus. It appeared she spent enough time on the cards to gather information.

Day 5, Group 1: The group began the third "Perplexing Situation." The operator started using the menu system, then began reading the "Aztec Society" chapter. She read sequentially, using the "Next" button to proceed. Five minutes were spent — long enough to gather appropriate information. This pattern would continue for the whole session. "Guides" were used twice.

Group 2

Day 1, Group 2. The operator went directly from the Main Menu to the chapter "Cortés and Montezuma." She used the index at the beginning of the chapter to find individual cards of information. She then returned to the index by use of the "Previous" button. She spent a total of 33 minutes in this fashion. She stayed on individual cards for only 4 seconds or less. There were 10 uses of the "Previous" button and two uses of a "Guide." Indications are that the operator was getting a feel for the interface and not reading much information. This may be in keeping with the observation that Day 1 was spent mostly in getting into the problem-solving steps, establishing effective working relationships, and finding out how to navigate the data base.

Day 2, Group 2. The operator went to the "Aztec Society" chapter. She spent 4 minutes on the "Aztec Empire" card. (The latter was particularly important at this point because the group was in the process of discovering how Cortés defeated the Aztecs.) Next, the user went to the "Spanish Treatment" chapter. She used the "next" button, which would advance the cards sequentially through the chapter. She looked at each card in the chapter, spending six minutes. The time indicates some reading may have taken place, not just browsing through the cards. (This chapter would offer only supporting information for the problem at hand; the chapter on Cortés and Montezuma would have been a better choice.) The user now explored the chapter on the origins of the Aztecs. The nine minutes spent here was inappropriate to the question at hand. She used the "next" button to go sequentially through this chapter. Finally, the user chose the Cortés and Montezuma chapter. Here she spent six minutes. This time she used the index at the beginning of the chapter and the "return" button to get back to the menu. This would indicate that she was using the card titles to find specific information — as opposed to using the "next button" to browse for information. For the last 10 minutes of class, this user went from card to card in the "Start" and "Puzzles" area — on the surface, this appears to be less-than-fruitful activity. The "guides" button was used only once during this session.

Day 3, Group 2. The group started on the second "Puzzles", human sacrifice. The students got off to a very slow start. For the first 28 minutes, the operator spent time in the "Start" and "Puzzles" chapters. It appeared she did not know exactly what she was doing. The trail goes from the beginning chapters mentioned above, to the "Gods and Human Sacrifice" chapter. The final fifteen minutes were spent navigating between the glossary and the "Gods and Human Sacrifice" chapter. She moved between them by using the "return" key and the main menus. The group discovered the audio recordings of the god's names in the glossary. Apparently the audio caught their interest because each name was played about six times. The "Previous" button was used twice; the "guides" button was not used.

Day 4, Group 2. The group started on the last "Puzzles", the origin of the Mesoamericans. The operator began in the "Start" and "Perplexing Situation" chapters, then went to the chapter on "Aztec Society", an appropriate choice. She went to the middle of the chapter, then used the "Back-one-card" button to move to the front — this is similar to flipping the pages of a book backwards. This activity lasted only one and a half minutes, so she was apparently just browsing. A 17 minute gap in the record may indicate a group conference intervened. The operator then spent 42 seconds looking at the "Mesoamerican Origins." The next activity can only be described as "not productive." The user quit the entire program , then re-opened the program and spent the rest of the time looking at the beginning chapters. "Guides" or the "Previous" buttons were not used.

Day 5, Group 2. The operator started in "Puzzles" for 7 seconds, then used the menu to go to the "Mesoamerican Mysteries" chapter. For the next 2.3 minutes, she browsed this chapter by using the "Next" button. With the exception of staying on the card about papyrus boats for 22 seconds, she looked at most cards for approximately three seconds. She used the menu system to explore "Puzzles", then visited the glossary where she listened to the audio recordings of "Nahuatl", "Montezuma", Tezcatlipoca", and "Encomienda."

Group 3

Day 1: This group immediately found a problem in the software. One of the guides in the "Puzzles" section linked the group not to "Cortés and Montezuma", but to the chapter on "Mesoamerican Mysteries". All of the groups had been given the first "Puzzles" on a piece of paper in order to save time, but users somehow have a knack for finding a problem that could have been prevented. This was a determined group, however, and they quickly made up for lost time. This group, unlike group 2, spent considerable time in the chapters. The operator moved to the chapters using the Main Menu. The group logged five minutes in one chapter, and 13 minutes in another.

Day 2, Group 3: A review of the audit trail indicates this user was seriously looking for information, and, in the right places. The group was researching the problem related to how Cortés was able to defeat Montezuma. The user started in the chapter on Cortés and Montezuma, then used the "Guides" button (5 times) and the "Previous" button (14 times) to go to and from the central chapter. The operator stayed basically in one chapter for 24 minutes. This suggests that less browsing was occurring, allowing more time for the gathering of information.

Day 3, Group 3: This day was spent in wrapping up the first "Perplexing Situation." The operator used the main menu to access the "Cortés and Montezuma" chapter; here he spent five minutes. While he used the "Guides" button only once, he started using the "Next" button to go through the cards. At some points, he spent nearly one minute on the cards, allowing plenty of time to gather information. Most of the group's time was spent with the teacher. They outlined for her their problem-solving steps, their hypothesis, and the supporting rationale.

Day 4, Group 3: A new operator was assigned today. Most of the time was spent in group work. The new user was not active with the computer until there was six minutes of class time remaining, at which point he found the audio buttons in the glossary. He spent six minutes listening to "Cortés", "Encomienda", "Nahuatl", and "Tezcatlipoca!" While the audio was of good quality, and the operator and others may have been learning, this activity probably took away from the other problem-solving activities.

Day 5, Group 3: The operator went directly to the "Cortés and Montezuma" chapter to find information about sacrifices. Although there was considerable information in this chapter, the chapter on "Gods and Sacrifices" would have been more appropriate. The operator used the "next" button to go through the cards. The glossary was used once.

Group 4

Day 1: The operator explored the data base for about 10 minutes. He then spent 13 minutes in the Cortés and Montezuma chapter, but was jumping from card to card so fast that little information was found. The "previous" button was used once.

Day 2, Group 4: Using the main menu, the operator went into the chapter on "Cortés and Montezuma." There was a good deal of browsing; the operator visited three chapters that were not directly related to the question under consideration. The operator primarily used the "Return to Menu" button and the "Return to Main Menu" button. Nearly eight minutes were spent in the "Cortés and Montezuma" chapter. The operator used the "Back-one-card" and "Next" buttons to navigate this chapter. The "Guide" button was used once; the "Previous" button, 17 times. The operator seemed proficient at returning to the menus for additional ideas. Individual cards were visited long enough to gather information.

Day 3, Group 4: The facilitator assigned a new operator — partly to engage a young student who had thus far preferred to "goof-off." This user was using the "Return to menu" and "Return to Main Menu" buttons, then using the menus for the next selection. He was visiting some inappropriate chapters, perhaps because he was learning the layout of the data base. Next, he went into the "Cortés and Montezuma" chapter for 10 minutes. Although he succumbed to the temptation to listen to "Nahuatl" 10 times in succession, it appeared he had gotten the feel for the interface. He was using the "Guides", "Previous", and "Return to menu" buttons effectively. Overall, this appeared to be a very effective computer session.

Day 4, Group 4: The facilitator reported that he changed the group leader on this day and that the group seemed to lose all momentum. The audit trail supports the facilitator's observation. The operator moved from chapter to chapter, staying little more than one minute in any area, even though the group had gone on to the problem about human sacrifice. The "Guides" button was used once. Most navigation was by use of the menu system.

Day 5, Group 4: This was a short session. The group moved into the third "Puzzles." Not much computer activity occurred. This was probably a function of the group's activity in going through the problem-solving process. The operator skipped around; with the exception of spending one and a half minutes on one card concerning "Early Migration", most cards were viewed for 13 seconds or less.

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