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A STUDY OF THE EFFECTS OF USING COMPLETE HYPERTEXT COMPARED
WITH THE EFFECTS OF USING FOCUSED HYPERTEXT IN THE DELIVERY
OF COMPUTER BASED INSTRUCTION.

DISSERTATION

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

By

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Denton, Texas

December, 1998

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The purpose of the study was to examine the impact that hypertext and hypertext design on the cognitive process. The study used two identical computer based lessons. One set of lessons used a complete set of hypertext resources that supported all of the learning objectives throughout the lessons. The other set of lessons focused the hypertext resources by limiting them to the immediate learning objective.

To measure the possible impact of the different treatments the study measured student performance, based on analysis of a Performance Achievement Pre-test and a Performance Achievement Posttest score. Both computer based lessons recorded student interactions and navigational choices during the research. The records were examined for differences based on group membership. The attitudes of participants in the study toward the use hypertext and computer-based learning was examined by the results of a Likert-like survey conducted at the end of the last lesson.

The lessons were designed using Authorware 4.03 and delivered on the Internet. The participants self enrolled and were assigned to one of the two groups at random. Participant records were updated every time the participants ended a session and stored in a database on an internet server. During the period of time the lessons were available

fifty one of nine hundred and seventy two people completed all components of the study to qualify for the research.

Three hypotheses were investigated. Statistical procedures included frequency distribution, Levene's Test for Equality of Variances, Independent Samples T-Test for Equality of Means and Cronbach's Alpha test of internal consistency. The differences between the means of the Pre-test and Posttest scores were significant. The differences between the means of the measures of interactivity and navigational options were significant for several items. There were few significant differences in the Likert-like survey of perceptions and attitudes towards computer based instruction.

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CHAPTER I

INTRODUCTION

Background

Developers of curricula intended for computer based instruction may choose from an increasing number of new hardware and software tools. Recent advancements in these development tools have given curriculum designers access to complete hypertext functionality as well as the ability to incorporate full hypermedia contextual on-line electronic performance support systems. These tools have made it easy for developers of computer based instruction in object-oriented programming environment to use hypertext and on-line help tutorials to enhance their lessons.

The expectations and familiarity that learners have using computer applications in a graphical interface environment, with button-bar design of support functions and navigational tools, have created a need for developers to try to meet these enhanced expectations by incorporating them in their computer based instructional designs. It is now almost impossible to view a computer based learning application that does not include hypertext and hypermedia as core components for navigation and support.

Frank M. Betts and Vicki E. Hancock (1995), Directors, ASCD Curriculum/Technology Resource Center attribute the use of hypertext in the classroom as a learning tool to simultaneous advances in five technologies:

1. The Graphical User Interface (GUI).
2. General Markup Languages (GML).
3. Data Compression.
4. Low-cost sound and video capture, due largely too inexpensive memory.
5. Increased computer-processing speed.

These technologies, coupled with an expanding use of telecommunications and the Internet's World Wide Web, have brought a high awareness, accessibility, acceptance, and preference of hypertext to the developers of curricula and to their participants as well.

There is concern over the use of Hypertext as an Integral Component of Computer Based Instruction (Clark,1995; Dede,1988; Gery, 1991; and Conklin, 1987). The growing number of learning options available to learners in a hypertext environment increases the cognitive demands on learners. This increased cognitive demand forces a level of self-monitoring of a student's own comprehension of information. The learning environment now forces learners to continually select appropriate strategies to integrate and synthesize information. These strategies, requiring additional efforts on the part of the learner while undertaking new information in a lesson, are known as meta-cognition strategies. "The richness of non-linear representation carries a risk of potential intellectual indigestion, loss of goal-directness, and cognitive entropy" (Dede,1988).

Conklin (1987), Clark (1994) and others, simply refer to the set of induced meta-cognition strategies as "cognitive-overload."

The cognitive load, defined as "the amount of information people can process," induced on learners in a multimedia learning environment must be managed for effective teaching (Clark, 1995). In a study involving the use of hypertext, Bowers and Tsai (1990), also "speculate on the presence of an additional cognitive load" induced on subjects by the use of new hypertext technologies.

While many have expressed a concern about cognitive overload, it has been established by Locatis, Letourneau & Banvard (1989), Heller (1990), and Jonassen (1991) that learners actually prefer the opportunity to use hypertext and the ability to select learning segments of an interactive computer program.

Early research on the use of hypertext and hypermedia found that completely non-sequential programs were perceived as disorderly and often led to "idiosyncratic and exceptional forms of connection" (Nelson, 1987).

The proper role of hypertext in education as an integral component of computer based instruction has been unclear (Heller, 1990). There is a need for research to attempt to measure the impact on the cognitive load and to guide the design of interactive multimedia to minimize its impact on learning.

Need for the Study

At this time, there has been little research comparing the use of and control of hypertext in computer based learning. In one experimental analysis of the use of hypertext (Way, 1992) compared the three methods of computer instruction:

1. Controlled hypertext, participant directed;

2. Linear, program directed; and
3. Instruction, linear, with repeating frames.

This study found neither benefit nor liability for the use of hypertext methodologies and suggested additional research. The study concluded that hypertext may be employed without detrimental effects, and may be a viable supplement to conventional instruction.

There is ample indication of a need for additional study. In order to fully control and measure the presence of any additional cognitive load, this research will need to incorporate two content equivalent versions of a complete computer based learning unit. Each unit will have lessons that offer hypertext, hypermedia and, in addition, each unit will need to contain sets of overviews and help files.

The design of the interface for both versions of the unit will also be identical. By making the content and interface essentially equal in both units, the researcher is then able to build in to the units two different sets of hypertext media. In addition to the equivalent content and interface controls, both units contain identical Pre-Test and Posttest instruments along with a Likert-type survey of participant attitudes.

The control unit will be a set of lessons supported by a full, or unfocused, set of hypertext. The experimental unit will be a set of lessons supported by a limited, or focused, set of hypertext.

The unfocused hypertext unit will not be limited to the current learning objective but will allow the participant full access to all of the resources at any time. The focused

hypertext unit will be limited to the current learning objective and will not allow the participant full access to all of the other resources.

Throughout this study the term focused hypertext will pertain to a design structure that limits the scope of hypertext to the current learning objective.

Both versions of the unit would include a full set of metrics. Metrics are variables that monitor, collect, and record the participant's path through the lesson and supporting applications.

The ability to create computer based learning units large enough to support a realistic hypertext environment along with the ability to monitor and record student interactivity and navigation has not been a practical, cost effective solution for researchers. In order to meet the full hypertext requirements for help and overviews, each of the two units of computer based lessons and supporting files would occupy at least twenty million bytes of disk space. In addition, a secure database will be needed to control access to the computer based units and store the estimated four thousand bytes of data generated by each participant. Design and construction of both units and associated application files would take about eight hundred hours.

To measure and assess the impact of the use of hypertext methodologies on computer based learning, a high level of monitoring and recording of the participant's interaction and path through the application is needed.

Authorware, a registered trademark of Macromedia, Inc., was selected as the authoring system in this study because it has more than four hundred variables and

functions built into it designed to record and monitor learner interaction and navigation (Elieson, 1993).

The Purpose of the Study

The purpose of this study was to examine the impact that hypertext and hypertext design places on the cognitive process by comparing the use of complete hypertext to the use of focused hypertext to determine if there is any measurable differences in:

1. Participant performance, based on analysis of the Study Performance Achievement Pre-test and the Study Performance Achievement Posttest scores,
2. The additional cognitive load as described by Bowers and Tsai (1990), Clark (1995), and
3. Attitudes and perceptions of learners toward the use hypertext computer based learning based on analysis of a Likert-type survey.

Hypotheses

H₀1: There will be no significant differences between the means of the unfocused group and the focused group on the gain score based on Pre-test and Posttest results.

H₀2: The means of the metrics used to measure the cognitive load in the unfocused group will not differ significantly from the means of the metrics used to measure the cognitive load in the focused group.

H₀3: There will be no significant differences in participant attitudes in the unfocused group from participant attitudes in the focused group.

Definition of Terms

The following definitions are provided for some of the terms used in this study.

Artificial Intelligence - Computer systems which perform functions normally associated with human reasoning and learning, processes such as imagination and intuition.

Browser - A software tool used to read electronic documents over the World Wide Web.

Cognitive Load - The amount of information people can process (Clark, 1995).

Electronic Personal Support System (EPSS) - An electronic system that provides integrated, on-demand access to specific information, tools and methodology to enable a high level of performance with a minimum of additional external support (Gery, 1991).

Focused Hypertext - Is designed to be limited to the current learning objective and does not allow the participant full access to other resources in the lesson.

FTP (File Transfer Protocol) - An accepted standard that allows network users to transfer their computer data to each other's computer.

General Markup Languages (GML) - Text or codes added to a document to convey information about it. Usually used to formulate a document's layout, or to create links to other documents or information servers. HTML and SGML are common forms of markup languages.

Hertz (Hz) - Unit of frequency--one Hz is equal to one cycle per second. Named in honor of Heinrich Hertz, first to detect such waves in 1883. Megahertz is one million hertz.

HTML - Hypertext Markup Language. A convention of codes used to access documents over the World Wide Web.

HTTP (Hypertext Transfer Protocol) - The protocol used to signify an Internet site is a World Wide Web site.

HyperCard - Brand-name for Apple/Mac product--simple authoring system for lower level interactive computerbased instruction or information management. A PC-based hypertext system is Quest or Linkway.

Hypermedia - Multi-level interactive computer-based instruction or information management system that includes video, slides, graphics, sound, and other systems controlled through the hypermedia system.

Hypertext - Multi-level interactive computer-based instruction or information management system consisting of nodes and their associated links.

Log-in/Log-out - Connecting with a computer, computer network, Intranet or an application.

Metacognition is "knowledge about their own cognitive processes and their ability to control these processes by organizing, monitoring, and modifying them as a function of learning outcomes" (Conklin, 1987) and "metacognition refers to an individual's ability

to accurately determine the goal of a given task, apply appropriate strategies to reach the goal, monitor progress towards the goal, and adjust strategies as necessary" (Clark, 1988).

Multimedia - Any document which uses multiple forms of communications media, such as text, audio, or video.

Node - Hypertext is a collection of nodes and their associated links. A node contains the content of a hypertext system.

Pixel - The point of blocked light on a video display screen, which creates a bit of the character seen.

Resolution - The clarity of the image on video display screen--three factors influence resolution: lines of resolution (vertical and horizontal), raster scan rate (number of times per second the image on a video screen can be refreshed or "lit up" again), and bandwidth.

RGB Monitor - Video display screen in color--Red, Green, Blue--in light waves, the three colors combined in different ways produce all other colors.

Unfocused Hypertext - is not always designed to be limited to the current learning objective and often allows the participant full access to any of the lesson resources at any time.

World Wide Web (Also known as WWW, W3, or the Web.) - A sophisticated, yet easy-to-use, protocol for navigating the Internet by means of hypertext.

Organization of the Study

This study is divided into five chapters. Chapter I contains the background, need, and purpose of the study. The hypotheses are stated along with a set of definitions of essential terms.

Chapter II is a collection of related, significant literature incorporating a brief history of hypertext, an overview of electronic personal support systems, issues and concerns for the use of hypertext, and its relationship to metacognition, cognitive overload.

Chapter III presents the research design, research treatment, and access to the research instruments, the population in the study, and the instrumentation used in the study.

An analysis of the research is presented in Chapter IV.

A summary of the findings, conclusions, and recommendations of the major areas of the study is presented in Chapter V. The areas include: the means of the Pre-test and Posttest, the participant's use of time during the research, the metrics or measurements used to study the cognitive load, and the Likert-type survey of learner attitudes and perceptions of the study.

The Appendix contains the testing and survey instruments along with an album of many of the screen graphics used in the study.

CHAPTER II

RELATED LITERATURE

The History of Hypertext

Vannevar Bush, as Director of Scientific Research and Development for the United States and Science Advisor to the president, created the concept of hypertext in 1935 (Horn, 1989). In an article published several years later in the Atlantic Monthly magazine, Bush predicted both the use of personal computers and hypertext documents when he wrote, "Consider a future device for individual use, which is a sort of mechanized private file and library.... in which an individual stores all of his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed flexibility" (Bush, 1945).

The device that Bush referred to was his Memex system, or memory expander. In an article that described Vannevar Bush's initial ideas for Memex, viewed as a first expression of the concept of hypertext, Nyce and Kahn (1989) commented that while Memex was never built it served as a prototype for all hypertext systems to come.

Bush describe Memex as having a scanner to enable the learner the ability to input new material. The material would be stored on microfilm and projected as the learner required. Bush stated that "... most of the contents are purchased on microfilm ready for

insertion. Books of all sorts, pictures, current periodicals, newspapers, are thus obtained and dropped into place. Business correspondence takes the same path."

After describing the use of microfilm and projection equipment Bush went on to state that "... the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another." This is the essential feature of the Memex. The process of tying two items together is the important thing.

Bush raised concern for the learner of this new technology with his suggestion that a new profession of "trail blazers" be established to come to the assistance of learners. The trail blazers would be those who find delight in the task of establishing trails through the enormous mass of the common record (Nielsen, 1990).

For twenty years after Bush's article in the Atlantic Monthly magazine little happened in the field of hypertext. The cost of computer processing effectively removed interest in using computers for word processing tasks.

In spite of this constraint, Douglas C. Engelbart, during his work at the Stanford Research Institute, was able to build the first working and usable hypertext system in 1962 (Horn, 1989). His Augment System, part of a project to develop computer tools to augment human capabilities and productivity, provided the vision for on-line knowledge workers (Engelbart, 1963). Engelbart's project was the first major effort in the area of office automation and word processing and embraced more concepts and tools than we currently enjoy in today's professional work environment.

One essential component of the Augment System was NLS, for oN-Line System that had several hypertext features. Engelbart presented NLS at a special session of the 1968 Fall Joint Computer Conference. The presentation was well received and referred to later by many as the catalyst for the development of interactive computing (Nielsen, 1990).

The term hypertext and the term hypermedia were first used to expand the growing vision of the technology by Theodor Nelson in conjunction with his product Xanadu (Horn, 1989). Nelson defined hypertext as ... computer-supported non-sequential writing. In an article where he also created the word "docuverse" to be a vision of all of mankind's documents linked together (Nelson, 1981). In describing Xanadu and his vision, Nelson says, Xanadu is not a large centralized software system but rather an idea for software running on a de-centralized network (Nelson, 1988).

The focus of Nelson's idea for Xanadu was that it was a central repository for everything that anybody has ever written and thereby a truly universal hypertext. Nelson's vision of hypertext as a literary medium, his primary book on hypertext is entitled Literary Machines, led him to believe that everything is deeply intertwined and therefore has to be online together.

The rapidly expanding use of unlimited hypertext was cause for several researchers to publish and share their concerns. Robert Glushko (1989) felt that multi-document hypertext is only called for in comparatively few cases. The learners must have explicit tasks that require the combination of information to use hypertext.

Several essential developments in hypertext are the results of university research. Andries van Dam created many experimental hypertext systems at Brown University. Van Dam also developed the first of many university instruction systems. One system helped teach a class in English poetry and another system assisted in the instruction of a cellular biology course (Horn, 1989).

Van Dam's Hypertext Editing System, built in 1967, was the world's first working hypertext system. It was able to run in a small 128K memory partition on an IBM/360 system. At the conclusion of the research project at Brown University, the Hypertext Editing System was sold to the Houston Manned Spacecraft Center where it was used to prepare documentation for the Apollo missions (Nelson, 1988).

Van Dam credited his second hypertext project, File Retrieval and Editing System (FRESS) to be the first application to have an "undo" option (Van Dam, 1988). FRESS was so robust it was able to run, unchanged, twenty years later at the 1989 Association for Computing Machinery (ACM) Hypertext conference.

The ZOG group at Carnegie-Mellon University developed the first hypertext menu system. The team consisted of Allen Newell, Donald L. McCracken, Robert Akscyn and George G. Robinson. ZOG was an attempt to create a system that would produce a rapid response in a large network through a simple menu selection interface. ZOG was implemented on a United States nuclear powered carrier, the USS Carl Vinson (Horn, 1989).

KMS, a commercial version of ZOG, was developed by the group soon after.

KMS, or Knowledge Management System, still currently implemented on Sun workstations, was described as any mixture of text, graphics, and image items, each of which may be linked to another frame or to invoke a program (Akscyn, McCracken & Yoder, 1987).

The first acclaimed hypermedia system was the Aspen Movie Map. Developed by Andrew Lippman at the Massachusetts Institute of Technology Architecture Machine Group, a precursor of the famous Massachusetts Institute of Technology Media Lab. The Aspen Movie Map was a travel application that permitted the learner to make a simulated drive through the city of Aspen on a computer system.

The system was created by taking photographs throughout the city using four cameras mounted on a vehicle. Photographs were taken at all intersections and several points in between at three-meter intervals. The images were stored on videodisks and retrieved not by requesting a single street address but by a linking system that gave the user the illusion of actually traveling throughout the city of Aspen. The learner also could stop and walk in shops and even adjust the seasonal weather conditions. The Aspen Movie Map demonstrated the use of hypermedia as a discovery tool and led the way for many multimedia applications today (Nelson, 1988).

The Architecture Machine Group, Richard A. Bolt and Nicholas Negroponte, at the Massachusetts Institute of Technology expanded the current vision of hypertext and hypermedia to include many new functions such as a built in calendars and calculators

and interactive graphics. The room they designed, constructed with several new functions in an attempt to insert a human into the computer environment as much as possible, was named "Spatial Dataland." Bolt and Negroponte are also credited with incorporating touch screen usage, joystick control, and speech recognition technology (Bolt, 1984).

The early hypertext systems were designed from research projects and developed as proof-of-concept-systems. In contrast, the Symbolics Document Examiner was designed and created as a commercial product (Walker, 1987). It was the first system to make use of an on-line manual for learner support. Intended for wide usage, the Symbolics Document Examiner was limited to a specific, expensive artificial intelligence workstation and beyond the reach of many.

In 1986, Peter Brown developed Guide, the first commercial system for both Apple's MacIntosh computer and IBM's personal computer (Horn, 1989). The Guide system incorporated scrolling text, pop-up windows and links to spreadsheets (Brown, 1987). Guide was the first widely available hypertext to run on ordinary affordable personal computers found in offices and in the home.

John Sculley, referring to Apple's Knowledge Navigator, described the possibilities for personal computers beyond the year 2010 stated, "Most important, the Knowledge Navigator will customize knowledge for you ... to make navigating through information and ideas as interesting and understandable as possible." To this concept Sculley added components consisting of a large, flat display screen with full color, high-definition, television quality images, full pages of text, graphics, and computer generated

animations. Sculley also considered incorporating the use of speech synthesis and speech recognition (Horn, 1989).

Scully realized the impact hypertext might have on learning. Education will not simply be a prelude to a career, but a lifelong endeavor. Some of the important elements that will promote this new paradigm for lifelong learning are:

1. The development of conceptual skills, and the ability to test validity against multiple points of view;
2. The nourishment of individual creativity and the encouragement of exploration;
3. The encouragement of collaboration, and an emphasis on clear communication (Scully, 1987).

Bill Atkinson's HyperCard was released in 1987, and given free along with the purchase of a computer helping to make it a widespread success. It is a full multi-functional software tool that includes many of the properties learners associate with hypertext and hypermedia (Horn, 1989).

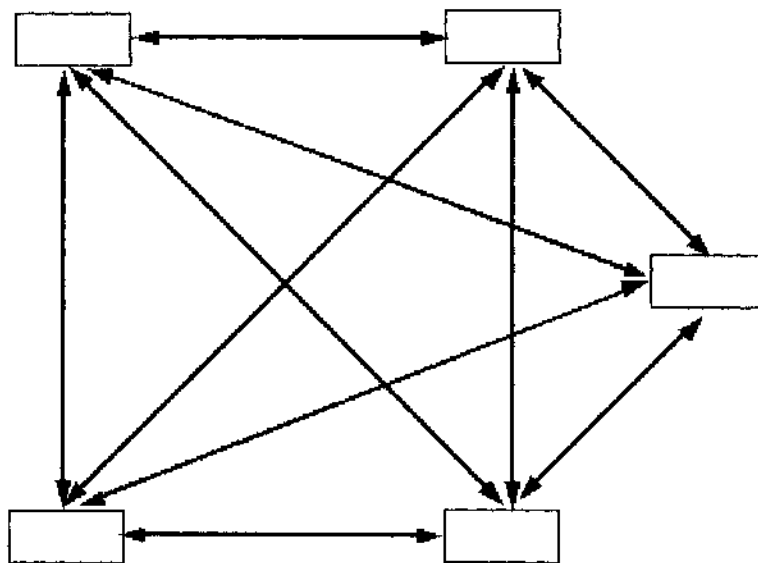
The Types of Hypertext

The design of hypertext includes several basic structures. The structures include: Unstructured Hypertext, Structured Hypertext, Hierarchical Hypertext, and Focused Hierarchical Hypertext (Jonassen, 1986).

Unstructured Hypertext

The characteristics of unstructured hypertext include random node linking with connections available from any node to any other node. The navigational path is recorded in the temporary memory of the computer so that it is possible to jump back to the previous nodes and to jump forward again to nodes already visited simply by clicking on the 'back' or 'forward' options.

Figure 1. Unstructured Hypertext



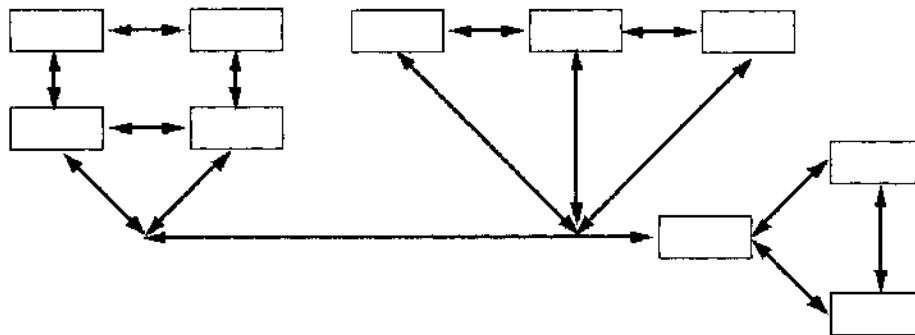
Unstructured hypertext promotes a comparison-contrast style of thinking.

Information is fragmented and the learner at risk of getting lost in levels.

Structured Hypertext

The characteristics of structured hypertext include an explicit and organized arrangement of nodes and associative links. The design implies a relationship between a knowledge structure and the structure of the nodes. Each structure is a conceptual model of the information (Frisse, 1988).

Figure 2. Structured Hypertext

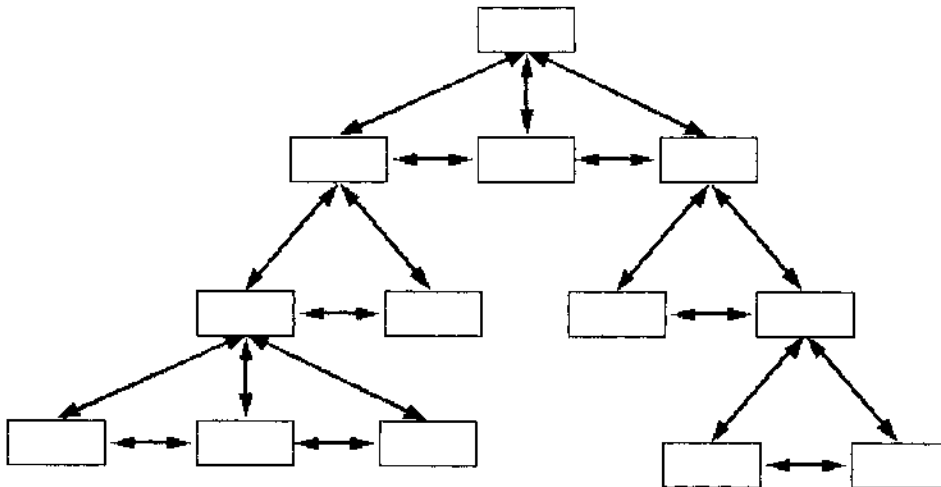


The nature of the node structure depends on the structure of the content as well as the type of information processing the designer intends for the learner.

Hierarchical Hypertext

Hierarchical hypertext represents a highly structured design. General concepts are at the top of the hierarchy with more detailed concepts broken down under them. Individual nodes or screens prompt various predefined hierarchical subordinate or superordinate relationships.

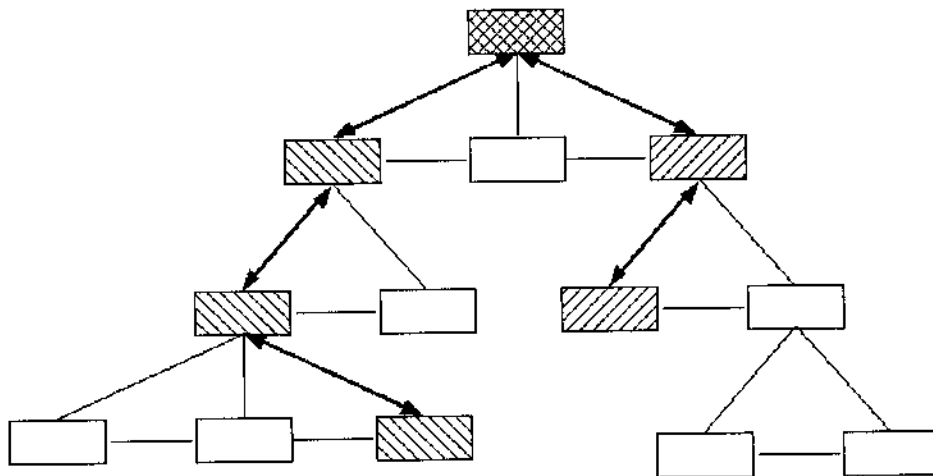
Figure 3. Hierarchical Hypertext



Focused Hypertext

Throughout this research the term "focused hypertext" will pertain to the use of a set of hierarchical hypertext that has been altered to limit the original set of node options to just the sequences that support the current behavioral objective.

Figure 4. Focused Hierarchical Hypertext



All of these structures embody the three basic characteristics that define a hypertext system (Conklin, 1987).

1. Information is chunked into nodes. A node could consist of a single word, definition, page or collection of media.
2. The nodes or chunks of information are linked to other nodes.
3. The path the learner elects to follow is to some degree "remembered" by the application.

Electronic Personal Support Systems (EPSS)

The development of hypertext systems has helped to create an age of information and a level of access to vast quantities of information. One effort to control or focus hypertext and hypermedia is through the design and implementation of an Electronic Personal Support System (EPSS).

An Electronic Personal Support System (EPSS) is an electronic system that provides integrated, on-demand access to specific information, tools, and methodology to enable a high level of performance with a minimum of additional external support (Gery, 1991). Another definition of an EPSS is the electronic infrastructure that captures, stores, and distributes individual knowledge assets to enable individuals to achieve required levels of performance in the fastest possible time and with a minimum of support from others (Raybould, 1995). Stevens & Stevens (1996) describe an EPSS as a computer application that can provide on-demand, task-specific skills training; task and situation specific information access; expert advice needed to solve unusually difficult or non-routine work problems; customized tools for job task automation; and embedded coaching, help, and validation tools, which together can improve human performance.

These definitions allow us to conclude that higher levels of performance, in general, may be achieved by supporting the learner in task-specific and situation-specific information, expert advice, and customized tools which should be available on demand at any time and any place (Gery, 1991).

The difference between an EPSS system and traditional learning can be seen first by summing up the four main benefits of an EPSS (Collis & Verwijs, 1995).

1. There is to be no delay between the review of the learning and the moment the knowledge is required.
2. The learner always has access to the latest information and procedures.
3. Support is possible, and inexpensive, even when the learners are widely dispersed.
4. Expert and detailed advice is always available.

These elements of an EPSS differentiate an EPSS from other types of learning systems to the degree that it integrates information, tools and advice. For example, this integration makes an EPSS different from a help system contained within a closed software application or an interactive online reference system, although either of these could be part of an EPSS (Gery, 1991).

In addition, Collis & Verwijs (1995) suggest a hybrid EPSS that combines with traditional educational software, they mention this integration as a difference between educational software and an EPSS. As a support mechanism, EPSS can be removed or ignored by the learner from the learning application as they feel their performance improves (Sherry and Wilson, 1996).

Two key and critical connections an EPSS shares with a traditional learning environment are Customized Tools and Expert Advice. Customized tools are the "cognitive artifacts (Norman, 1995), that extend cognitive ability by abstracting the

procedure or task from irrelevant details, and that extend the memory by relieving [the learner] of the necessity of remembering the details ..." (Sleight, 1995). Expert advice may take the form of an interactive expert system that asks the learner questions and, based on the learner's responses, uses case-based reasoning to guide learners through decision-making processes. These systems use specially designed data-gathering and validation processes to transfer human knowledge to a computer (Stevens & Stevens, 1996).

By integrating Artificial Intelligence (AI) capabilities into an EPSS, coaching and intelligent advice are provided through Intelligent Tutoring Systems (McGraw, 1994). For example, an Intelligent Tutoring System could compare learner performance to a knowledge base to determine an appropriate level of support, to diagnose learning problems, and provide customized suggestions. The more intelligent the expert system, the closer the EPSS simulates a human tutor or coach. However, without proper instructional design and focus to the behavioral objectives, the system does little more than help the users get to inadequate or irrelevant conclusions faster (Gery, 1991).

Issues and Concerns

Several authors have expressed concern for the possible adverse impact the use of hypertext may have on the learning process (Gery, 1991; Dede, 1988).

Carol Kaehler reported that authors of hypertext and interactive multimedia have the ability to create large and complex learning environments that can easily annotate with hypertext and navigational options raising two challenges:

1. How to prevent learners from being overwhelmed by the amount of information available;

2. How to show learners where they are in a system (Kaehler,1988).

The issues and concerns according to Horn (1989) comprise two main categories:

1. Design and Authoring issues;

2. Learner issues.

The design and authoring issues include:

1. The creation of learning applications is labor intensive;

2. The maintenance of learning applications is labor intensive;

3. Multiple skills and a new rhetoric are needed for the authors of learning applications;

4. The design of the content of nodes and the representation of the links.

The learner issues include:

1. Awareness of preference toward serial or holistic reading skills;

2. Getting lost in hyperspace;

3. Poor metacognition skills that may limit usage of the learning application;

4. The presence of overchoice and related cognitive overload.

Metacognition and Cognitive Overload

The last two items under the learner issues are explained as:

1. Metacognition is "knowledge about their own cognitive processes and their ability to control these processes by organizing, monitoring, and modifying them as a function of learning outcomes" (Conklin, 1987) and "metacognition refers to an individual's ability to accurately determine the goal of a given task, apply appropriate strategies to reach the goal, monitor progress towards the goal, and adjust strategies as necessary" (Clark, 1988);

2. Overchoice and related cognitive overload refers to the additional learning that must occur for the learner to cope with the choices the learner must make to navigate through the learning application and the additional metacognition skills the learner must acquire or employ during the lesson at the same time they are attempting to learn new skills (Clark, 1994).

As stated by Horn (1989), "Learners with poor metacognitive skills are unlikely to make the choices involved in self-instruction required by hypertext and hypermedia and are most likely to suffer from the problems of cognitive overload.

Two major views of "attention" exist in the cognitive science literature (Glass & Holyoak, 1986). One view asserts that there is a finite amount of attention for a learner to use, which may be divided among several task components simultaneously. The other view suggests that attention can be made to only one task component at a time, with the

learner putting the other task components on hold. In either case, the learner must control attention using the proper set of metacognitive skills.

Organization and Design of the Study

The tools used in the field of computer based instructional design have seen technological advances demanding that developers constantly examine new ways to construct learning and training applications. As the designers and developers struggle to learn the tools used to create new courses for deployment on the World Wide Web, those learning the new tools often overlook a very important part of the process: sound instructional design. Far too often, given the demands of fast-paced corporate and educational life, learning and training applications are being thrown into the World Wide Web or a company intranet without regard for the basics of good instructional design. There is concern that without sound instructional design, the impact of the free use of hypermedia, originally intended to support the learning or training experience, adds greatly to the cognitive load and thus diminishes the quality of the application.

The traditional computer based instructional model has evolved into four distinct pedagogical models, as reported by Coffin & Thurnau (1991). These four pedagogical models emerged during the development of Project FLAME (Foreign Language Applications in Multimedia Environment). They address different teaching and learning needs and together form the basis for a complete system. A brief description of the pedagogical model includes:

The Teacher's Partner. This component is designed to present the course content and to supplement the teacher's presentation. The teacher has control of the presentation with little interaction on the part of the learner.

The Learner's Partner. Highly interactive, this component is designed to be used by one or more learners working independently. The primary use of this component is to introduce new subject matter, to complement materials already presented, to practice new skills, and to review. The lessons are self-paced, responsive to individual needs, and provide extensive feedback.

The Exploratory Lessons. This component is designed to function as an electronic textbook and allow learners to follow up on their classroom activities away from the classroom. Topics are more extensively explored and offer a variety of explanations and review. There is little feedback and no opportunity for input.

The Creative Medium. This component in the pedagogical model provides the most effective ways for learners to explore subject matter. Participants are given the tools to author their own multimedia presentations.

The research and control instruments to be used in this study were designed as a Learner's Partner.

The addition of hypertext to the cognitive load expressed by Bowers and Tsai (1990) and Clark (1995) was quantified by measuring several components of hypertext learning segments in an interactive computer program. These interactive components consisted of navigational options, response options, and exploratory options. The

navigational options within the lessons include buttons to permit the participant to move to the next page or frame, to move to the previous page or frame, to move back to the introduction of the lesson, and to move to the main menu of the application. In addition, there were buttons giving the participant access to all of the overviews and to the application help system.

The response options within the practice quizzes included buttons containing the distracters for the multiple-choice questions and graphical representations of essential elements of the lessons for participant selection.

The exploratory options included hypertext keywords and graphical representations of essential elements of the lessons for participant exploration. The measurements associated with each interactive component were referred to as the metric of each interactive component.

In another study (Grabinger, R. Scott, 1993) the cognitive load induced by multimedia demonstrated that the technology associated with the use of multimedia was a double-edged sword.

On one hand, multimedia adds a positive blend of audio, color, animation, and video channels. Multimedia also allows the developer to assault learners with a level of cognitive overload way beyond other less powerful instructional media tools. In addition, the ability to create hyperlinks in the text and in the media that take the participant to other content within the lesson or even outside of the lesson must have an additional

adverse impact on the cognitive load. It is important to be able to verify and measure this induced cognitive load on learners.

Since all of the participant's physical involvement or interaction with learning segments in computer based instruction is quantifiable by measurements called metrics, the presence of an additional cognitive load can be expressed by examination of the these metrics used to measure participant interaction.

Examples of the metrics used in this study include recording how far the mouse is moved on the screen, how many times the participant selects a navigational option and how many minutes were spent taking the Posttest.

However, additional studies have found neither benefit nor liability of using hypertext as an integral component of computer-based instruction (Lanza & Roselli, 1991; van den Berg & Watt, 1991). For now, the use of hypertext is considered a supplement to conventional instructional design and may be employed without demonstrated detrimental effects. The use of hypertext in itself, while considered by some to be a desirable feature of computer instruction, has failed to demonstrate any educational advantage. No statistically significant differences in the eventual Posttest performances have been observed. While the flexibility of movement within the instructional program has resulted in significantly longer time on tasks, this extra time has not correlated with better Posttest performance. Several possible reasons have been offered for the lack of improved performance.

1. The amount of time the participant took to select an item and the amount of time the computer took to locate and present the response frame induced additional delays that may have contributed to the longer times required to complete the task found in some studies. The contribution of each of these time delays induced by hypertext has not been independently evaluated and the extent of the contribution of each therefore, has not been determined. Hypertext and the ability to navigate throughout the lesson inherently contain a dimension of learning that has made interpretation of the supposed advantages of these enhancement variables difficult if not impossible to isolate.

2. Advocates of programmed instruction propose that building competence in a learner should not be accomplished by random introduction of content-instruction, rather, the building of competence requires a learner to move from simple well-known concepts to progressively more difficult concepts.

3. The concept of difficulty, however, is related to the degree of a learner's preparation for new material. Thus, the amount of time spent on a given task can vary in different ways for each participant throughout an instructional program. Giving the participant control over response options, navigational options, and exploratory options adds to the total time needed for completion of the lesson. Failure to incorporate the metrics or measures associated with the time taken by these activities creates a fundamental problem common to all research which employs test scores in an attempt to quantify "time to completion" to measure participant performance.

4. The use of hypertext has revealed little empirical evidence concerning learning issues. Most claims in support of hypertext are based on the associative linking that hypertext allows. Hammond (1989) suggested that although "the review of literature is enthusiastic [it is] largely uncritical. " The linking of information, that is, the paths navigated by the learner, appears to be important in the study of learning processes. Evidence seems to suggest that high ability learners may benefit from the use of hypertext. The inclusion of advanced organizers may also allow the low ability learner to benefit from the use of hypertext-based learning (Joyce, 1992; Locatis, Letourneau & Banvard, 1989).

5. Some problems related to hypertext include the possibility of disorientation. According to Heller (1990), who has questioned hypertext in learning presentations, the inclusion of referenced maps, diagrams that offer visual references to the participant's path through the lesson, accessed through a common icon or response button should improve recall and comprehension that will be a benefit to the learner.

As reported by Bowers and Tsai (1990) in a study involving the attempt to measure any additional cognitive load induced on learners by the use of hypertext, there is a need for a detailed methodology that would establish and record the participant's path through the lesson. Such methodology would incorporate collection of the metrics associated with the participant's path, one that indicated which nodes were visited and how much time was spent at each node.

By recording the frequency and duration of all of the elected interactions, any differences in performance, as measured by Pre-Test to Posttest scores would be related to participant's chosen path through the lesson. Since the cognitive load is impacted by any expansion of the meta-cognitive skill set needed to cope with the participant's chosen path through the lesson, the metrics are a critical component to understanding the cognitive load.

CHAPTER III

METHODOLOGY

Research Design and Treatment

This study was conducted in an attempt to respond to questions raised in previous studies pertaining to the effectiveness of hypertext functionality on summative performance in computer based instruction. These questions included:

1. Would there be significant differences in performance between the focused hypertext group and the unfocused hypertext group?
2. Would there be significant differences between the means of the metrics, or the measures of participant interactivity and navigational selections, between subjects using two different levels of Hypertext?
3. Would there be significant differences between the attitudes and perceptions of subjects using two different levels of Hypertext?

Thus, the purpose of this study will be to examine the impact that hypertext and hypertext design may place on the cognitive load by comparing the use of unfocused hypertext to the use of focused hypertext in computer based learning. Then, to determine if there are any measurable differences in participant performance, attitudes and perceptions toward the use hypertext in computer based learning.

Access to the Research Instruments

The instructional material used in this research was made available to anyone with an Internet connection to the World Wide Web. The instructional materials used were designed to function with the following minimum configuration for each host: an IBM compatible personal computer with a clock speed of at least 90 MHz, a minimum of 2 megabytes of random access memory, a color monitor set to display standard 256 colors at a resolution of 640 pixels by 480 pixels, and a modem capable of maintaining an internet connection of at least 28.8 kps.

Procedures

The participants in this study self-enrolled by using the last six digits of their social security number as their logon identification. In addition, each subject was required to create a personal password that, when used in conjunction with his or her logon identification, assured their uniqueness and maintained their privacy throughout the research process.

This procedure is shown in the figures displayed in Appendix B. Figure 5 is a view of the index HTML page found on the research web site. This page provides basic information about the research and alerts the potential participant to the need for the plug-in required by the participant's Internet browser to view the Authorware application.

The screen represented by Figure 6 establishes the level of security required to run the application fully and permits the application to use the participant's computer's hard drive and to transfer files to the researcher's Internet provider's server. Figure 9 shows

the identification screen where each participant uniquely registers for the research using a combination of six digits and password they have created themselves.

The first time the participant enters the research they are requested to provide a small set of demographics.

Their logon identification was used to randomly assign them either to the control group or to the experimental group. Each subject was required to supply the following demographic data prior to participating in the research: gender, male or female; and current educational level, elementary school, middle school, high school, college undergraduate or college graduate.

Figure 10 is the demographic sign-on screen.

Instrumentation

The two computer based instructional materials used in this study were each developed by the researcher using Authorware 4.0.3. The two instructional materials were identical in every way except that the control treatment incorporated a full set of hypertext resources that included Help, Overviews, and Pop-up definitions of keywords. The experimental treatment focused the hypertext resources to the topics covered in the current lesson unit and limited to the current learning objective. The participant had limited or focused access to Help, Overviews, and Pop-up definitions of keywords.

The control group treatment and the experimental group treatment each consisted of:

1. A computer based instruction course,

2. A Study Performance Achievement Pre-test,
3. A Study Performance Achievement Posttest, and
4. A Likert-type survey of attitudes.

The computer based instruction course is a survey of the history and development of computers and consists of seven fifteen-minute lesson segments. Each segment presents significant advances in computer technology spanning a given period of time. At the end of each segment, the participants were presented with a practice quiz covering the topics of the segment. The practice quiz and lesson segment could have been taken as often as the participant wished.

The Study Performance Achievement Pre-test and Study Performance Achievement Posttest consisted of forty randomly generated multiple choice questions. The Study Performance Achievement Pre-test was required to be taken before the participant began the computer based instruction course.

The Study Performance Achievement Posttest could not be taken before the participant completed all seven fifteen-minute lesson segments, including practice quizzes.

The Likert-type survey was offered instead of a practice quiz at the end of the seventh segment. Both treatments were designed to be taken by the participant in 9 fifteen-minute sessions making the entire research project take two hours and fifteen minutes to complete.

All participant responses to the computer-based instruction were monitored by the lesson application software and recorded in individual text files on an Internet server.

The data include participant demographics, Study Performance Achievement Pre-test and Study Performance Achievement Posttest responses, results of the Likert-type survey and a set of measurements designed to track participant progress and positioning throughout the computer based instruction. Each measurement, or metric was designed to measure part of the induced cognitive load during participant interaction of the delivery of computer based instruction. The metrics included:

1. Total number of mouse clicks,
2. Total mouse movement measured as distance between mouse clicks expressed in pixels,
3. Total time expended by the participant on the set of lessons,
4. Total time expended by the participant on the entire unit,
5. Total time expended by the participant on each section of the lesson,
6. Total time expended by the participant on practice tests,
7. Frequency of use of each of the hypertext activities including a help file, glossary file, pop-up keywords and graphic identifications,
8. Total time expended on each of the hypertext activities including a help file, glossary file, pop-up keywords, and graphic identifications.

A Likert-type attitude scale was incorporated into the last computer based lesson and several aspects of participant attitude toward the process were recorded immediately at the conclusion of the last segment. The unique participant record folders were created at the time of the initial participant logon and stored on the server of the Internet provider

for access by the researcher. Given two content equivalent learning units, each with identical interface design but with different levels of hypertext support, any differences in performance will be quantifiable by comparing their identical collection of embedded metrics.

CHAPTER IV

ANALYSIS OF THE DATA

The Statistical Package for the Social Sciences SPSS Graduate Pack version 8.0 for Windows was used in the analysis of the data collected. The records in the database recovered from the Internet server indicated fifty-one participants completed the study.

Pre-Test and Posttest Means

The treatment for the control group, labeled the "unfocused" group, consisted of full set of hypertext words and full access to the entire set of overviews and help files. The unfocused group contained twenty-six participants consisting of ten males and sixteen females. The scores of the unfocused group on the Study Performance Achievement Pre-test ranged from 17% to 80% with a mean of 43.42%. The scores of the unfocused group on the Study Performance Achievement Posttest ranged from 42% to 92% with a mean of 68.26%, as shown in Table 1.

The treatment for the research group, labeled the "focused" group, consisted of limited hypertext words and controlled access to the set of overviews and help files. The focused group contained twenty-five participants consisting of twelve males and thirteen females. The scores of the focused group on the Study Performance Achievement Pre-test ranged from 35% to 62% with a mean of 44.48%. The scores of the focused group on the

Study Performance Achievement Posttest ranged from 62% to 92% with a mean of 80.120%, as shown in Table 1.

Table 1

Descriptive Statistics– Focused and Unfocused Groups

	Unfocused Group		Focused Group	
	Pre-Test	Posttest	Pre-Test	Posttest
N	26	26	25	25
Range	63.000	50.000	27.000	30.000
Minimum	17.000	42.000	35.000	62.000
Maximum	80.000	92.000	62.000	92.000
Sum	1129.000	1775.000	1112.000	2003.000
Mean	43.423	68.269	44.480	80.120
Std. Error	3.300	2.800	1.042	1.581
Std. Deviation	16.826	14.278	5.213	7.907
Variance	283.134	203.885	27.177	62.527

The frequencies of scores for the Unfocused Hypertext Group's Study Performance Achievement Pre-test are shown in Table 2.

Table 2

Frequencies: Unfocused Group's Pre-test

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	17.00	1	.0	3.8	3.8
	20.00	2	.0	7.7	11.5
	25.00	1	.0	3.8	15.4
	30.00	3	.1	11.5	26.9
	32.00	1	.0	3.8	30.8
	35.00	1	.0	3.8	34.6
	37.00	2	.0	7.7	42.3
	40.00	2	.0	7.7	50.0
	42.00	1	.0	3.8	53.8
	45.00	1	.0	3.8	57.7
	47.00	2	.0	7.7	65.4
	50.00	1	.0	3.8	69.4
	52.00	3	.1	11.5	80.0
	55.00	1	.0	3.8	84.6
	57.00	1	.0	3.8	88.5
	60.00	1	.0	3.8	92.3
	65.00	1	.0	3.8	96.2
	72.00	1	.0	3.8	100.0
	75.00	1	.5	100.0	
	80.00	1	99.5		
Total		26	100.0		

The frequencies of scores for the Unfocused Hypertext Group's Study

Performance Achievement Posttest are shown in Table 3.

Table 3

Frequencies: Unfocused Group's Posttest

		Cumulative			
		Frequency	Percent	Valid Percent	Percent
Valid	42.00	1	.0	3.8	3.7
	47.00	1	.0	3.8	7.7
	50.00	1	.0	3.8	11.5
	52.00	1	.0	3.8	15.4
	55.00	2	.0	7.7	23.1
	57.00	2	.0	7.7	30.8
	60.00	2	.0	7.7	38.5
	62.00	1	.0	3.8	42.3
	67.00	2	.0	7.7	50.0
	70.00	2	.0	7.7	57.7
	72.00	2	.0	7.7	65.4
	77.00	1	.0	3.8	69.2
	80.00	1	.0	3.8	73.1
	82.00	2	.0	7.7	80.8
	85.00	2	.0	7.7	88.5
	87.00	1	.0	3.8	92.3
	90.00	1	.0	3.8	96.2
	92.00	1	.0	3.8	100.0
	Total	26	.5	100.0	
			99.5		
Total			100.0		

The frequencies of scores for the Focused Hypertext Group's Study Performance Achievement Pre-test are shown in Table 4.

Table 4

Frequencies: Focused Group's Pre-test

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	35.00	1	.0	4.00	4.00
	37.00	1	.0	4.00	8.00
	42.00	9	.2	36.00	44.00
	45.00	11	.2	44.00	88.00
	50.00	1	.0	4.00	92.00
	55.00	1	.0	4.00	96.00
	62.00	1	.0	4.00	100.00
	Total	25	.5	100.00	
			99.5		
	Total		100.0		

The frequencies of scores for the Focused Hypertext Group's Study Performance Achievement Posttest are shown in Table 5.

TABLE 5

Frequencies: Focused Group's Posttest

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	62.00	1	.0	4.00	4.00
	65.00	1	.0	4.00	8.00
	67.00	1	.0	4.00	12.00
	70.00	2	.0	8.00	20.00
	77.00	2	.0	8.00	28.00
	80.00	4	.1	16.00	44.00
	82.00	6	.1	24.00	68.00
	85.00	2	.0	8.00	76.00
	87.00	3	.1	12.00	88.00
	92.00	2	.0	8.00	96.00
	95.00	1	.0	4.00	100.00
	Total	25	.5	100.00	
			99.5		
Total			100.0		

Pre-Test and Posttest Means

The analysis of the Pre-Test and Posttest means was conducted to test the first hypothesis.

H₀1: There will be no significant differences between the means of the unfocused group and the focused group on the gain score based on Pre-test and Posttest results.

The data were examined to determine whether both groups derive from normal populations with the same or unequal variance. The Levene Test was used to determine that both groups came from populations of equal variance or from populations that do not have homogeneity-of-variance.

The Levene Test is less dependent on the assumption of normality than most tests. For each case, it computes the absolute difference between the value of that case and its cell mean and performs a one-way analysis of variance on those differences. The Levene's Test is especially helpful with analysis of variance (Norusis, 1993).

When the Levene significance level for homogeneity-of-variance is a value greater than .05, the statistics used are those generated by assuming equal variances. When the significance indicated is a value less than .05 the statistics used are those generated by not assuming equal variances.

The group statistics for the Pre-Test and Posttest scores are shown in Table 6.

Table 6

Group Statistics

	Type	N	Mean	Std. Deviation	Std. Error Mean
Pre-test	Unfocused	26	43.4231	16.8266	3.3000
	Focused	25	44.4800	5.2131	1.0426
Posttest	Unfocused	26	68.2692	14.2788	2.8003
	Focused	25	80.1200	7.9074	1.5815

One-way ANOVA assumes that the variances of the groups are all equal. Alpha was set at .05 for each examination. The result of the applying the Levene test for homogeneity of variances yields a significance value of .07, which exceeds .05, indicating that the variances of the groups are equal and the assumption is justified. This data is being tested in conjunction with the first hypothesis.

The SPSS Independent-Samples One-Way ANOVA procedure was used to compare the change in the means in the Pre-test and the Posttest scores. The dependent variable was defined as the difference between the Pre-Test and Posttest scores for both groups.

Table 7

One-way ANOVA, Confidence Interval .95

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1484.895	1	1484.895	18.992	.000
Within Groups	3831.145	49	78.187		
Total	5316.039	50			

Note. Dependent variable = Posttest Score – Pre-Test Score.

The study on the dependent variable representing gain in test scores, revealed significant differences in the means of Pre-test and Posttest scores between the focused hypertext group and the unfocused hypertext group.

The mean gain in score for the focused hypertext group was 35.64 while the mean gain in score for the unfocused hypertext group was only 24.8461.

The focused hypertext group results showed a significant (Sig.<=.000) difference in the mean gain in score.

Metrics used in the Measurement of Cognitive Load

An analysis of the metrics used in the measurement of cognitive load was conducted to test the second hypothesis.

H₀2: The means of the metrics used to measure the cognitive load in the unfocused group will not differ significantly from the means of the metrics used to measure the cognitive load in the focused group.

Thirteen metrics, or measures that focused on interactivity and navigational choices, were recorded throughout the application in order to study participant activity.

TIME_QUIZ	The total time expressed in minutes, that the participant spent taking the practice quizzes.
TIME_LIKE	The total time expressed in minutes, that the participant spent taking the Likert-type survey.
TIME_HELP	The total time expressed in minutes that the participant spent in the Help area.
TIME_OVER	The total time expressed in minutes that the participant spent in the Overview area.
TIME_PRE	The total time, expressed in minutes, that the participant spent taking the Pre-test.
TIME_POST	The total time expressed in minutes, that the participant spent taking the Posttest.
TIME_LESSON	The total time expressed in minutes, that the participant spent in the Lesson area.
TIME_TOTAL	The total time expressed in minutes that the participant spent in the application.
T_MOUSE	The total distance expressed in pixels, that the mouse moved during the application.

T_CLICK	The total number of mouse clicks made by the participant during the application.
T_LEFT	The total number of times the participant selected the LEFT button during the application.
T_RIGHT	The total number of times the participant selected the RIGHT button during the application.
T_HELP	The total number of times the participant selected the OVERVIEW or HELP buttons during the application.

The variables selected in the research to monitor participant interaction and navigational choices are basic to most computer based learning applications. What role each interaction makes and how significant that role is to the creation of the cognitive load was examined.

Table 8

Group Statistics for Metrics

Variable	Unfocused Hypertext Mean	Focused Hypertext Mean	Unfocused Hypertext Std. Deviation	Focused Hypertext Std. Deviation
TIME_QUIZ	18.358	15.960	3.458	4.039
TIME_LIKE	4.081	3.784	.288	.237
TIME_HELP	35.215	30.404	10.261	7.526
TIME_OVER	6.150	5.604	.947	1.056
TIME_PRE	10.650	10.776	2.059	2.679
TIME_POST	11.908	10.964	2.121	2.004
TIME_LESSON	65.754	64.204	7.764	5.700
TIME_TOTAL	133.757	125.736	15.941	9.854
T_MOUSE	29966.692	30245.680	2384.892	1655.644
T_CLICK	455.500	497.2000	50.464	28.1395
T_MAIN	9.807	8.400	1.096	1.224
T_RIGHT	61.346	67.960	12.289	9.615
T_HELP	76.115	94.6000	22.695	24.178

The Independent-Samples t-Test procedure was used to compare the group means.

Table 9

t-Test for Equality of Means, 95% Confidence Interval, Metrics

	t	df	Sig. (2-tailed)	Unfocused Hypertext Mean	Focused Hypertext Mean	Mean Difference
TIME_QUIZ	2.255	49	.029	18.358	15.960	2.398
TIME_LIKE	4.002	49	.000	4.081	3.784	.297
TIME_HELP	1.903	49	.063	35.215	30.404	4.811
TIME_OVER	1.945	49	.057	6.150	5.604	.546
TIME_PRE	-.188	45	.852	10.650	10.776	-.126
TIME_POST	1.632	49	.109	11.908	10.964	.944
TIME_LESSON	.810	49	.422	65.754	64.204	1.550
TIME_TOTAL	2.170	42	.036	133.757	125.736	8.021
T_MOUSE	-.487	45	.629	29966.692	30245.680	-278.987
T_CLICK	-3.663	39	.001	455.500	497.2000	-41.701
T_LEFT	1.940	40	.059	9.807	8.400	7.075
T_RIGHT	-2.135	49	.038	61.346	67.960	-6.613
T_HELP	-2.81	49	.007	76.115	94.6000	-18.484

These variables demonstrate a significant two-tailed difference between their respective group means (Sig. < .05).

TIME_QUIZ	The total time, expressed in minutes, that the participant spent taking the practice quizzes. The means indicate the time spent taking practice quizzes by the unfocused hypertext group was significantly more than the time spent on practice quizzes by the focused hypertext group.
TIME_LIKE	The total time, expressed in minutes, that the participant spent taking the Likert-type survey. The means indicate the time spent taking Likert-type survey by the unfocused hypertext group was significantly more than the time spent on Likert-type survey by the focused hypertext group.
TIME_TOTAL	The total time, expressed in minutes, that the participant spent in the application. The means indicate the time spent in the application by the unfocused hypertext group was significantly more than the time spent in the application by the focused hypertext group.
T_CLICK	The total number of mouse clicks made by the participant during the application. The means indicate the number of mouse clicks made by the focused hypertext group was

significantly more than the number of mouse clicks made by the unfocused hypertext group.

T_RIGHT The total number of times the participant selected the RIGHT button during the application. The means indicate the number of times the RIGHT button was selected by the focused hypertext group was significantly more than the number of times the RIGHT button was selected by the unfocused hypertext group.

T_HELP The total number of times the participant selected the OVERVIEW or HELP buttons during the application. The means indicate the number of times the OVERVIEW or HELP buttons were selected by the focused hypertext group was significantly more than the number of times the OVERVIEW or HELP buttons were selected by the unfocused hypertext group.

A low significance value for the t-Test (Sig. ≤ 0.05), as shown in Table 9, indicates that there is a significant difference between the means of the two groups.

Table 10

Participant's Use of Time

	Mean Unfocused Hypertext	Mean Focused Hypertext	Significance
Total Time in Application	133.757 minutes	125.736 minutes	.036
=			
Time in the Set of Lessons	65.754 minutes	64.204 minutes	.422
+			
Time in Help	35.215 minutes	30.404 minutes	.063
+			
Time in Overviews	6.150 minutes	5.604 minutes	.057
+			
Time in Pre-test	10.650 minutes	10.776 minutes	.852
+			
Time in Posttest	11.908 minutes	10.964 minutes	.109
+			
Time in Likert-type Survey	4.081 minutes	3.704 minutes	.000
+			
Time in Practice Quizzes	18.358 minutes	15.960 minutes	.029
+			
Miscellaneous Time	18.359 minutes	15.88 minutes	-----

Note. Miscellaneous Time consists of participant's physical inactivity or application delays due to file transfers and processing time.

Participant Attitudes

An analysis of the Likert-type survey of participant attitudes was performed to test the third hypothesis.

H₀₃: There will be no significant differences in participant attitudes in the unfocused group from participant attitudes in the focused group.

The set of Likert-type survey variables and statement items is shown in Table 11.

Table 11

Likert-type Survey Variables

Variable	Statement
LIKE1	I covered all of the history lessons.
LIKE2	I completed the practice quiz for each section.
LIKE3	I read the contents of each text box.
LIKE4	My mouse skills are good.
LIKE5	I used the Overview button often.
LIKE6	My typing skills are good.
LIKE7	I used the Help button often.
LIKE8	The logon procedure was easy for me.
LIKE9	I am uncomfortable using a computer.
LIKE10	The Main Menu was helpful.

(table continues)

Variable	Statement
LIKE11	I spent about 10 minutes on each lesson, including quiz.
LIKE13	I would choose computer lessons over paper notes.
LIKE14	I spent about 20 minutes on each lesson, including quiz.
LIKE15	The pictures of the inventions were not needed.
LIKE16	I did well on the practice quizzes.
LIKE17	I spent about 30 minutes on each lesson, including quiz.
LIKE18	I could find everything I needed.
LIKE19	The computer lessons were easy to use.
LIKE20	I would choose paper notes over computer lessons.
LIKE21	I would like to see more computer-assisted classes.
LIKE22	I recommend students use both computer lessons and paper notes.
LIKE23	I spent most of my time on the practice quizzes.
LIKE24	I re-read the lessons to do better on the practice quizzes.
LIKE25	I can identify the main events in the History of Computers.
LIKE26	I usually do well when I work with computers.
LIKE27	I found all of the buttons easy to use.
LIKE28	I feel the Help and Overview buttons gave me more information.
LIKE29	I recommend that computer lessons be used to present this topic.
LIKE30	Without computer lessons I would have had to spend more time studying.

Cronbach's Alpha, a statistical test for internal consistency, was used on the survey and returned a value of .69.

Initial analysis of the data showed the thirty survey statements to have no significant intercorrelations.

Table 12 represents the sum of the participant responses for both groups. The key for the response totals is:

SA = Strongly Agree

A = Agree

N = Neutral or Not Apply

D = Disagree

SD = Strongly Disagree

TABLE 12

Likert-type Survey: Unfocused and Focused Groups

	Statement	SA	A	N	D	SD
1	I covered all of the history lessons.	36	12	3	-	-
2	I completed the practice quiz for each section.	37	17	-	-	-
3	I read the contents of each text box.	16	22	12	1	-
4	My mouse skills are good.	15	18	18	-	-
5	I used the Overview button often.	20	25	8	-	-
6	My typing skills are good.	7	17	19	7	1
7	I used the Help button often.	20	16	8	5	2
8	The logon procedure was easy for me.	29	17	4	1	-
9	I am uncomfortable using a computer.	9	5	24	8	5
10	The Main Menu was helpful.	7	13	22	6	3
11	I spent about 10 minutes on each lesson, including Quiz	4	7	16	16	8
12	I was comfortable using the "PageRight/Left" buttons.	1	19	19	12	-
13	I would choose computer lessons over paper notes.	17	18	10	5	1

(table continues)

	Statement	SA	A	N	D	SD
14	I spent about 20 minutes on each lesson, including Quiz.	18	12	14	7	-
15	The pictures of the inventions were not needed.	-	2	17	19	13
16	I did well on the practice quizzes.	17	32	2	-	1
17	I spent about 30 minutes on each lesson, including Quiz.	-	29	5	13	6
18	I could find everything I needed.	15	18	3	14	1
19	The computer lessons were easy to use.	8	20	9	14	-
20	I would choose paper notes over computer lessons.	3	17	17	14	-
21	I would like to see more computer assisted classes.	22	14	10	5	-
22	I recommend students use both computer lessons and paper notes.	14	11	17	9	-
23	I spent most of my time on the practice quizzes.	17	11	10	11	2
24	I re-read the lessons to do better on the practice quizzes.	11	17	12	11	-
25	I can identify the main events in the History of Computers.	18	10	16	6	1

(table continues)

	Statement	SA	A	N	D	SD
26	I usually do well when I work with computers.	13	12	18	8	-
27	I found all of the buttons easy to use.	15	17	12	7	-
28	I feel that using the Help and Overview buttons gave me more information.	7	19	13	11	1
29	I recommend that computer lessons be used to present this topic.	12	11	14	14	-
30	Without the computer lessons I would have had to spend more time studying.	10	16	15	6	4

The SPSS Independent-Samples t-Test procedure was used to compare the changes in the means of the scored items in the survey for both groups. Table 13 displays the two-tailed level of significance (alpha = .05) for each of the Likert-type survey questions.

Table 13

t-Test for Equality of Means, Likert

Variable	t	Df	Sig. (2-tailed)	Mean Difference
LIKE1	1.066	45.664	.292	.1462
LIKE2	.532	49	.597	.0677
LIKE3	-1.409	49	.165	-.3123
LIKE4	-.525	49	.602	-.1200
LIKE5	.046	49	.964	.0092
LIKE6	.493	49	.625	.1338
LIKE7	.967	49	.338	.3108

(table continues)

Variable	t	Df	Sig. (2-tailed)	Mean Difference
LIKE8	1.858	49	.069	.3708
LIKE9	-1.314	49	.195	-.4277
LIKE10	.438	49	.663	.1292
LIKE11	-.897	49	.374	-.2877
LIKE12	-.480	49	.633	-.1108
LIKE13	-.053	49	.958	-.0169
LIKE14	-.283	49	.778	-.0862
LIKE15	-.954	49	.345	-.2292
LIKE16	.613	49	.543	.1262
LIKE17	-.729	49	.470	-.2308
LIKE18	-.154	49	.878	-.0538

(table continues)

Variable	t	Df	Sig. (2-tailed)	Mean Difference
LIKE19	-.466	49	.643	-.1400
LIKE20	-.863	49	.392	-.1969
LIKE21	.551	49	.584	.1585
LIKE22	2.853	49	.006	.8077
LIKE23	-.816	49	.418	-.2908
LIKE24	-3.977	49	.000	-1.0785
LIKE25	1.619	43.635	.113	.5000
LIKE26	1.164	46.307	.250	.3369
LIKE27	1.624	49	.111	.4615
LIKE28	1.994	49	.052	.5646
LIKE29	-.563	49	.576	-.1800
LIKE30	-1.912	49	.062	-.6108

The Likert-type items with a low significance value for the t-Test ($p < .05$) and with a 95% confidence interval for the mean difference that did not contain zero indicate a significant difference exists.

The Likert-type survey items that demonstrated significant differences include:

LIKE22 I recommend participants use both computer lessons and paper notes.

LIKE24 I re-read the lessons to do better on the quizzes.

Presentation of Findings

The purpose of this section is to present the results of the analysis of the data.

There were three hypotheses in the study. Each hypothesis was stated separately with the findings presented after each hypothesis.

Alpha was set to .05 and a One-way ANOVA was used to compare the means of the gain score for each group. Table 4 shows that study on the dependent variable representing gain in test scores, displays significant differences ($\text{Sig.} \leq .000$) in the means of the Pre-test and Posttest scores between the focused hypertext group and the unfocused hypertext group.

This is important because it tells us that participation in the focused hypertext group itself is related to improved test scores.

The t-Test for Equality of Means was applied to the set of metrics. Of the thirteen variables shown in Table 9 used in the metric study, six have means with significant differences between groups.

The six variables represented the following participant behaviors:

1. The total time the participant spent taking the practice quizzes. The means indicate the time spent taking practice quizzes by the unfocused hypertext group was significantly more than the time spent on practice quizzes by the focused hypertext group.

2. The total time, the participant spent taking the Likert-type survey. The means indicate the time spent taking Likert-type survey by the unfocused hypertext group was significantly more than the time spent on Likert-type survey by the focused hypertext group.

3. The total time, the participant spent in the application. The means indicate the time spent in the application by the unfocused hypertext group was significantly more than the time spent in the application by the focused hypertext group.

4. The total number of mouse clicks made by the participant during the application. The means indicate the number of mouse clicks made by the focused hypertext group was significantly more than the number of mouse clicks made by the unfocused hypertext group.

5. The total number of times the participant selected the RIGHT button during the application. The means indicate the number of times the RIGHT button was selected by the focused hypertext group was significantly more than the number of times the RIGHT button was selected by the unfocused hypertext group.

6. The total number of times the participant selected the OVERVIEW or HELP buttons during the application. The means indicate the number of times the OVERVIEW

or HELP buttons were selected by the focused hypertext group was significantly more than the number of times the OVERVIEW or HELP buttons were selected by the unfocused hypertext group.

The t-Test for Equality of Means was applied to the set of Likert-type items. Of the thirty items in the survey as shown in Table 9, two have means with significant differences between groups.

The two variables represented the following participant attitudes or perceptions:

1. I recommend participants use both computer lessons and paper notes.
2. I re-read the lessons to do better on the quizzes.

A complete set of Likert-type statements used in the survey are shown in Table

11.

CHAPTER V

FINDINGS AND CONCLUSIONS

The following section will address the findings and conclusions of the first hypothesis:

H₀1: There will be no significant differences between the means of the unfocused group and the focused group on the gain score based on Pre-test and Posttest results.

Pre-Test and Posttest Means

The results of the study indicate that the mean score on the Pre-test and Posttest and of participants participating in the focused hypertext study differ significantly from the mean score on the Pre-test and Posttest of participants participating in the fully hypertext study.

The study on the dependent variable representing gain in test scores, revealed significant differences in the means of Pre-test and Posttest scores between the focused hypertext group and the unfocused hypertext group. The focused hypertext group results showed a significant (Sig.<=.000) difference in the mean gain in score.

The mean gain in score for the focused hypertext group was 35.64 while the mean gain in score for the unfocused hypertext group was only 24.8461. The significance in the gain in score is important to developers of instruction intended for computer based

learning for it implies that by focusing the design of hypertext to support the current learning objective better participant performance may be achieved.

Participant Time in the Study

The following section will address the findings and conclusions of the second hypothesis:

H₀2: The means of the metrics used to measure the cognitive load in the unfocused group will not differ significantly from the means of the metrics used to measure the cognitive load in the focused group.

There is a demonstrated relationship in gain in score based on group membership. The set of metrics or measures of participant activity were examined to determine which, if any, were indicators of the difference in the means of the performance by identifying those activities that significantly indicate membership by group.

The indicators comprised four main groups:

1. Participant Time in the Study,
2. Help and Overview,
3. Movement through the Application,
4. Time spent on Practice Quizzes and Time spent on the Likert-type Survey.

The differences in the use of time between the unfocused hypertext group and the focused hypertext group were measured by several variables. Table 14 outlines the difference and significance of the time spent on the set of lessons compared to the time spent on the entire application.

Table 14

Significance of Time on Lesson and Application

Total Time Expressed in minutes	Mean Unfocused	Mean Focused	Significance
Total Time in Set of Lessons	65.754	64.204	.422
Total Time in Application	133.757	125.736	.036

Note: Time in application = Time in Lessons + Time in Help + Time in Overviews + Time in Tests + Time in Survey + Time in Practice Quizzes + Time in Navigation.

Table 14 shows that there is no significant differences in time spent in the set of lessons by each group. There are significant differences between the means of each group when we examine the entire application.

These differences were brought into focus by an analysis of how time was used by the participants in each group. It is important to note that the total time spent on the application is the sum of time on the set of lessons, tests, survey, practice quizzes, help, overviews, participant inactivity and computer processing. This study did not attempt to address the last two activities.

There are no significant differences associated with the amount of time spent on the set of lessons by group. The mean of the unfocused group is 65.75, while the mean of the focused group is 64.20. There is, however, significance associated with the total time spent on the entire application (Sig.<=.036).

That is, the time spent viewing content was the same for both groups. To find an explanation for the performance differences the metrics associated with participant activity outside of the lesson content was examined

Help and Overview

The variables associated with participant activity on performance supporting activities such as Help and Overview was examined for indicators related to group membership and related performance scores was examined.

The time spent in Help and the time spent in Overviews did not reveal any significant group differences. However, the total number of times the Help section and the Overview section were selected was significant. The focused group selected these two areas of performance support significantly ($\text{Sig.} \leq .007$) greater than the number of times the unfocused group selected them.

The unfocused environment permitted exploration into areas outside of the initial concern the participant may have had when initiating the Help or Overview activity. This extra time spent off-task added to the share of total time spent on the learning activity. The focused environment immediately placed the participant into an area of support directly associated with the current learning activity.

Table 15 shows the two-tailed significance ($\alpha = .05$) for the help and overview total participant time and total number of times selected.

Table 15

Help and Overview: Total Time and Number Selected

	Means Unfocused Hypertext	Means Focused Hypertext	Sig. (2-tailed)
Total Help Time (minutes)	35.215	30.404	.063
Total Overview Time (minutes)	6.150	5.604	.057
Total Help (selected) + Overview (selected)	76.115	94.600	.007

Note: The first two rows are measures of time in each area and are not significant. The third row is a measure of the total times each option was selected and is significant.

Movement through the Application

The measures associated with movement through the application, represented by the variables recording total mouse clicks (Sig. \leq .001) and total clicks on the 'Right' button (Sig. \leq .038), also are significantly associated with group membership.

The means for each hypertext group using total number of mouse clicks throughout the lessons, the number of 'Right' button clicks, representing forward movement through the lessons, and the total time in the lessons are shown in Table 16.

Table 16

Total Number of Mouse Clicks, Right Button Selected and Time in Lessons

	Mean Unfocused Hypertext	Mean Focused Hypertext
Total Mouse Clicks	455.500	497.200
Total 'Right' Button Selected	61.346	67.960
Time in Set of Lessons	65.754	64.204

Note: Time in application = Time in Lessons + Time in Help + Time in Overviews + Time in Tests + Time in Survey + Time in Practice Quizzes + Time in Navigation.

These two metrics, total mouse clicks and total "Right" button selected, reflect the behavior of a learner re-reading and reviewing lesson content. Where was no significant difference between the total time in the set of lessons given the significant improvement on Posttest scores shown by the focused group, they made better use of time in the application.

Time on Practice Quizzes and Likert-type Survey

The time, expressed in minutes, expended on these activities by the participants in the focused group was less than the time, in minutes, expended on these activities by the unfocused group. The time spent on practice quizzes (Sig.<=.029) and the Likert-type survey (Sig.<=.000) are significantly related to membership by group and to related improvement on Posttest scores.

A comparison of the use of time, in minutes, by each group is shown in Table 17.

Table 17

Comparison of Time on Quizzes and Survey by Group

	Mean Unfocused Hypertext	Mean Focused Hypertext
Time on Practice Quizzes & Likert Survey	22.439	19.744

It is important to note that there were no significant differences in the time spent on the Pre-test, the Posttest or on the total time spent on the lessons by the groups. An explanation for the differences in time expended on the Likert-type survey may require additional study.

Participant Attitudes

The following section will address the findings and conclusions of the third hypothesis:

H₀₃: There will be no significant differences in participant attitudes in the unfocused group from participant attitudes in the focused group.

Two of the thirty items of the Likert-type survey indicated significant differences according to group membership.

1. "I recommend participants use both computer lessons and paper notes."
2. "I re-read the lessons to do better on the quizzes."

Two attitudes address improved results on the Posttest scores. The first, "I re-read the lessons to do better on the quizzes." is supported by the quantitative measures as shown in Table 13.

The attitude toward the use of computers: "I recommend participants use both computer lessons and paper notes." may in themselves be conducive of participant behavior that lends itself to improved results on the Posttest scores.

The fact that there were little differences between the focused hypertext group and the unfocused hypertext group in their attitudes and perceptions as reflected on the Likert-type survey reinforce fact that the groups are homogenous and that the random group assignment procedure was effective.

Recommendations

Based on the finds in this study the following recommendations are made:

1. The use of hypertext, and hypermedia, in a learning environment must be controlled or focused by the developers of curricula to the current learning objective. We should not assume an unlimited amount of time exists for learners to master each concept. The tools for computer based learning make it relatively easy, and inexpensive for developers to include full use of Help systems and hypertext links to related content in the courses they create. To do so without consideration of the impact to the participant's cognitive load will only degrade performance and diminish learning.

This study demonstrated that membership in a group, whose hypertext and navigational options were focused to the current learning objective, was significantly related to performance on a criterion-referenced test.

2. Additional study will be required to better understand the role each navigational activity and each hyperlink has to contribute directly to improved performance. Several measurements of learner interactivity were recorded in an attempt to understand the possible relationship between these activities and related performance in this study. However, the metrics involved only directly indicated membership in either the unfocused hypertext group or the focused hypertext group. The metrics were merely indicators.

Additional studies will be needed to incorporate a fuller range of quantitative and qualitative assessments. These assessments may include the recording of participant reaction and comment during the lessons as well as after the lessons (Horn, 1989; Gery, 1991; Kaehler, 1988; Dede, 1988; Conklin, 1987; and Clark, 1994).

Conclusion

This study has shown that the concern for the use of hypertext in learning applications designed to be delivered as computer based instruction has paralleled the development of hypertext systems. Early research on the use of hypertext revealed that nonsequential, unstructured hypermedia applications were perceived by participants as disorderly and would lead to idiosyncratic and exceptional forms of connection (Nielsen, 1990).

This study has built on the research conducted by M. W. Way at the University of South Florida, Tampa. This study also supports the publications of Conklin (1987) and Clark (1994) who have expressed concern for cognitive overload.

Without the capabilities and ease of use of a development tool such as Authorware, with its rich collection of built-in functions and variables, research efforts such as this one could not be designed.

As the power of the tools used to create learning applications has grown, so has the ability to add hypertext support features such as Help, Overviews and Electronic Performance Support Systems.

Learners have grown accustomed to this type of support and prefer using them (Bowers, D. and Tsai, C.,1990).

This study has shown that if the support systems are designed and constructed to align with the current learning objective that the impact to the learner's cognitive load is not significantly impacted and the learner is better able to focus on the learning objective. Performance, measured as scores on criterion-referenced test, will improve.

APPENDIX A
STUDY PERFORMANCE ACHIEVEMENT TEST QUESTIONS

The _____ was the first known machine developed to help perform mathematical computations. It is thought to have originated between 600 and 500 B.C., either in China or Egypt. Round beads, usually made of wood, were slid back and forth on rods or wire to perform addition and subtraction.

- A. AUDION
- B. ABACUS
- C. ENIAC
- D. UNIVAC

Just before he died in 1617, the Scottish mathematician who is better known for his invention of logarithms developed a set of calculating sticks called _____. This device was to be a strong influence upon the development of the slide rule and subsequent calculating machines which relied upon logarithms.

- A. Gates' 'Capron'
- B. Steiger's 'Millionaire'
- C. Jacquard's 'Loom'
- D. Napier's 'Bones'

In 1621, the _____ was invented by the English mathematician William Oughtred. The device, called 'Circles of Proportion' was a set of rotating discs which were calibrated with Napier's logarithms. One of the first analog computing devices, it was used commonly (in a linear array) until the early 1970s, when hand-held calculators started to become more popular.

- A. first super computer
- B. first transistor
- C. first slide rule
- D. first microprocessor

In 1623 the first mechanical calculator was designed by Wilhelm Schickard in Germany. Called the _____, the machine incorporated Napier's logarithms onto rotating cylinders in a large machine housing. One was commissioned for Johannes Kepler, the famous mathematician, but it was destroyed by fire before it was finished.

- A. "Calculating Clock"
- B. "Pascaline"
- C. "Logical Piano"
- D. "Colossus"

In 1642, the first automatic mechanical calculator was invented by the French mathematician and philosopher Blaise Pascal. Called the _____ the device was able to multiply and subtract, using a system of interconnected gears to advance digits. The machine was originally developed to simplify Pascal's father's tax collection work. Although the device was never a commercial success as Pascal had hoped, the principle of the interconnected gears was to find use in subsequent generations of mechanical calculators.

- A. "Calculating Clock"
- B. "Pascaline"
- C. "Logical Piano"
- D. "Colossus"

The first general-purpose calculating machine was invented by the German mathematician _____ in 1673. The device was a departure from the Pascaline, as it operated using a cylinder of stepped teeth rather than the series of interconnected gears. Although the device was able to perform multiplication and division, it suffered from reliability problems which diminished its utility.

- A. Gottfried von Leibniz
- B. Herman Hollerith
- C. Charles Babbage
- D. Alan M. Turing

In 1769, the _____ was invented by Baron Kempelen, a Hungarian nobleman. The device and its secrets were given to Johann Nepomuk Maelzel, an inventor of musical instruments, who toured Europe and the United States with the device in the late 1700's and early 1800's. Purported to be a pure machine, it featured a "robotic" player guided solely by automated mechanical means. It was a sensation wherever it went, but many commentators, including the famous Edgar Allen Poe, have written elaborate criticisms discounting that it was a "pure machine." Instead, it generally is held that the device was operated by a human hidden in the cabinet below. It was destroyed in a fire in 1856.

- A. "Colossus"
- B. "Butterfly"
- C. Steiger's "Millionaire"
- D. "Automaton Chess Player"

_____ was invented in 1804. Inspired by musical instruments which were programmed using punched paper, the machine featured a loom attachment which could automatically control weaving patterns using a line of punched cards. This idea, which revolutionized silk-weaving, was to form the basis of many future computing devices and programming languages.

- A. Gates' "Capron"
- B. Steiger's "Millionaire"
- C. Jacquard's "Loom"
- D. Napier's "Bones"

In 1822, _____ completed his "Difference Engine," a machine which could be used to perform calculations of simple tables. The Difference Engine was a complex assembly of wheels, gears, and ratchets engineered to exacting specifications. It laid the foundation for him to design his "Analytical Engine," a general-purpose device which was to be capable of performing any type of mathematical calculation. The plans of the analytical engine were the first clear conceptualization of a machine which could perform the type of computations which is now considered at the heart of computing.

- A. Gottfried von Leibniz
- B. Herman Hollerith
- C. Charles Babbage
- D. Alan M. Turing

In 1869, the first logic machine to use Boolean Algebra to solve problems faster than humans was invented by William Stanley Jevons. The machine, called the _____, used an alphabet of four logical terms to solve complicated syllogisms.

- A. "Calculating Clock"
- B. "Pascaline"
- C. "Logical Piano"
- D. "Colossus"

In 1885, the first successful _____ was invented by Dorr Eugene Felt. To save expense in building the model of the device, called the "Comptometer," Felt purchased wooden macaroni boxes to be used to house the devices. Within the next two years, Felt sold eight of them to the New York Weather Bureau and the U.S. Treasury. The device was used primarily for accounting, but many of them were used by the U.S. Navy in engineering computations, and was probably the most popular accounting machine in the world at the time.

- A. sketch-pad
- B. flip-flop circuit
- C. key-driven calculator
- D. Altair-MITS

In 1886, the first tabulating machine to use a punched card system of data entry was invented by _____. It was developed for use in tabulating the 1890 U.S. census, in which a population of 62,979,766 was tabulated. It's punch allowed an operator to aim a pointer in a matrix of holes, whereupon a hole would be punched in a blank card at the back of the machine. After the census, the inventor founded the Tabulating Machines Company, which, through merging and acquiring other companies, became what is today International Business Machines (IBM).

- A. Gottfried von Leibniz
- B. Herman Hollerith
- C. Charles Babbage
- D. Alan M. Turing

In 1893, the first successful automatic multiplying machine, _____, as it was called, automated Leibniz's invention of 1673, and was manufactured by Hans W. Egli of Zurich. Originally made for businesses, science found immediate use for the device and several thousand of them sold over the forty years which followed.

- A. Gates' "Capron"
- B. Steiger's "Millionaire"
- C. Jacquard's "Loom"
- D. Napier's "Bones"

In 1906, the first vacuum tube was invented by an American inventor, Lee De Forest. _____, as it was called, had three elements within an evacuated glass bulb. The elements were capable of detecting and amplifying radio signals received from an antenna. The vacuum tube was to find use in several of the early generations of computers, beginning in the early 1930's.

- A. AUDION
- B. ABACUS
- C. ENIAC
- D. UNIVAC

In 1919, the first bistable multivibrator or _____ was developed by American inventors W.H. Eccles and F.W. Jordan. The flip-flop allowed a circuit to have one of two stable states, which were interchangeable. It formed the basis for the binary bit storage format of today's computers.

- A. sketch-pad
- B. flip-flop circuit
- C. key-driven calculator
- D. Altair-MITS

In 1936, the first general model of logic machines was developed by _____. The paper, entitled "On Computable Numbers," was published in 1937 in the Proceedings of the London Mathematical Society and described the limitations of a hypothetical computer. Computable numbers were those numbers which were real numbers, capable of being calculated by finite means. He offered proof which showed that even when using a finite and definite process for solving a problem, certain problems still could not be solved. The notion of the limitations of such problem-solving was to have a profound impact upon the future development of computer science.

- A. Gottfried von Leibniz
- B. Herman Hollerith
- C. Charles Babbage
- D. Alan M. Turing

In 1950, the first real-time, interactive computer was completed by a design team at MIT. The _____, as it was called, was a revamped U.S. Navy project for developing an aircraft simulator. The Whirlwind used a cathode ray tube and a light gun to provide interactivity. It was linked to a series of radars and could identify unfriendly aircraft and direct interceptor fighters to their projected locations. It was to be the prototype for a network of computers and radar sites (SAGE) acting as an important element of U.S. air defense for a quarter-century after 1958.

- A. WHIRLWIND
- B. TRADIC
- C. RAMAC
- D. ABC

In 1939, the first truly electronic digital computer was developed at Iowa State College by Dr. John V. Atanasoff and Clifford Berry. The prototype, called the _____, was the first machine to make use of vacuum tubes as the logic circuits.

- A. WHIRLWIND
- B. TRADIC
- C. RAMAC
- D. ABC

In 1958, the development of a programming language, called _____, allowed research in artificial intelligence (AI) to develop.

- A. LISP
- B. BASIC
- C. COBAL
- D. FORTRAN

In 1956, the first system for storing files to be accessed randomly was completed. The _____ 305 could access any of 50 magnetic disks. It was capable of storing 5 million characters, within a second. In 1962, the concept was expanded with research in replaceable disk packs.

- A. WHIRLWIND
- B. TRADIC
- C. RAMAC
- D. ABC

In December 1943, the first English electronic calculator was developed for cryptoanalysis. The _____, as it was called, was developed as a counterpart to the Enigma, Germany's code machine. Among its developers was Alan M. Turing, developer of the Turing machine, who had escaped from the Nazis a few years before. It had five processors, each of which could operate at 5,000 characters per second. By using special registers and an internal clock, the processors could operate in parallel (simultaneously) which was to give it an overall speed of 25,000 characters per second. This high speed was essential in the code-breaking effort during the war. It's design was to remain classified information until many years after the war.

- A. "Calculating Clock"
- B. "Pascaline"
- C. "Logical Piano"
- D. "Colossus"

In 1947, the _____ was invented at Bell Laboratories by John Bardeen, Walter H. Brattain, and William Shockley. The developers received the Nobel Prize in 1956 for their work. The device is a small component which allows regulation of the flow of electric current and its use as a switch enabled computers to become much smaller and subsequently led to the development of microelectronic technology.

- A. first super computer
- B. first transistor
- C. first slide rule
- D. first microprocessor

In 1944, the first American program-controlled computer was developed by Howard Hathaway Aiken. The _____, as it was called, was patterned after Charles Babbage's designs for the analytical engine of a hundred years before. Punched paper tape carried the instructions and telephone relays controlled number wheel registers. It measured fifty feet long and eight feet tall, with almost five hundred miles of wiring, and was used at Harvard University for 15 years.

- A. NOVA
- B. Butterfly
- C. PDP-8
- D. Automatic Sequence Controlled Calculator (ASCC)

In 1946, the first large-scale electronic digital computer became operational. _____ used a system of externally mounted switches and plugs to program it. The instrument was built by J. Presper Eckert Jr. and John Mauchly.

- A. AUDION
- B. ABACUS
- C. ENIAC
- D. UNIVAC

From 1950 to 1962, a number of developments advanced computer technology. Once electronics technology had been applied to computing machines, computers were able to advance far beyond their previous abilities. Guided by Turing's model for logic machines, computer researchers integrated advanced logic into the machines. Programmers were able to exploit these utilities better once the first structured programming language, _____, was invented.

- A. LISP
- B. BASIC
- C. COBAL
- D. FORTRAN

In 1957, the first high-level programming language was introduced by a team at IBM. _____ was developed to improve automatic programming and is still in use by many scientists, engineers, and mathematicians.

- A. LISP
- B. BASIC
- C. COBAL
- D. FORTRAN

In 1951, the first commercially-available computer was delivered to the Bureau of the Census by the Eckert Mauchly Computer Corporation. The _____ was the first computer which was not a one-of-a-kind laboratory instrument. It became a household word in 1952 when it was used on a televised newscast to project the winner of the Eisenhower-Stevenson presidential race with stunning accuracy.

- A. AUDION
- B. ABACUS
- C. ENIAC
- D. UNIVAC

In 1954, the first general-purpose computer to be completely transistorized was built at Bell Laboratories. The _____ held 800 transistors and bettered its predecessors by functioning well aboard airplanes.

- A. WHIRLWIND
- B. TRADIC
- C. RAMAC
- D. ABC

In 1962, the first graphics program to allow the user to draw interactively on a display screen was developed by Ivan Sutherland at MIT. The program, called _____, used a light gun to input graphics on a CRT screen.

- A. sketch-pad
- B. flip-flop circuit
- C. key-driven calculator
- D. Altair-MITS

In 1963, the _____, the first commercially successful minicomputer, was distributed by Digital Equipment Corporation. The advent of commercial minicomputing was to have a significant influence upon the development of university computing science departments. The distribution of this 12-bit computer opened the floodgates of the minicomputer market for other companies.

- A. NOVA
- B. Butterfly
- C. PDP-8
- D. Automatic Sequence Controlled Calculator (ASCC)

A month after IBM's System/360 was introduced, the first _____ program was run at Dartmouth College by its inventors, Thomas Kurtz and John Kemeny. _____ was to become the introductory language for a whole generation of computer users.

- A. LISP
- B. BASIC
- C. COBAL
- D. FORTRAN

In 1964, the _____, to be commercially available, was shipped by the Control Data Corporation. The CDC 6600 had several data reel banks and was to remain the most powerful computer for many years after its development.

- A. first super computer
- B. first transistor
- C. first slide rule
- D. first microprocessor

In 1969, the first 16-bit minicomputer was distributed by Data General Corporation. The computer, called the _____, was an improvement in speed and power over the 12-bit minicomputer.

- A. NOVA
- B. Butterfly
- C. PDP-8
- D. Automatic Sequence Controlled Calculator (ASCC)

In 1971, the _____ chip was introduced by Intel Corporation. The 4004 chip was a 4-bit processor with 2250 transistors, capable of almost the same power as the 1946 ENIAC (which filled a huge room and featured 18,000 vacuum tubes). The 4004 chip measured 1/6-inch long by 1/8-inch wide.

- A. first super computer
- B. first transistor
- C. first slide rule
- D. first microprocessor

In 1971, the _____ was built and distributed by John Blankenbaker. The computer, called the Kenbak-1, had a memory capacity of 256 bytes, displayed data as a set of blinking LED's and was tedious to program.

- A. first Reduced Instruction Set Computer (RISC)
- B. first Macintosh Computer
- C. first personal computer
- D. first computer to use the Intel 80286 microprocessor chip

In January 1975, Micro Instrumentation Telemetry Systems introduced the _____. A more personal mini-computer, the _____ was an inexpensive (\$350) system unit which had no keyboard, monitor, or memory storage device, but did carry the 8-bit Intel 8080 microprocessor. Paul Allen and Bill Gates (later to co-found Microsoft Corporation) developed a version of BASIC as a programming language for the computer.

- A. sketch-pad
- B. flip-flop circuit
- C. key-driven calculator
- D. Altair-MITS

In 1980, the _____ prototype was developed by a research team at IBM. The 801 minicomputer used a simple set of instructions in machine language, which could be executed very fast (usually within one machine cycle). It is thought by many that this is the format for most future processors, due to their speed and efficiency.

- A. first Reduced Instruction Set Computer (RISC)
- B. first Macintosh Computer
- C. first personal computer
- D. first computer to use the Intel 80286 microprocessor chip

In 1981, the first commercial parallel-processing computer was distributed by BBN Advanced Computers, Inc. The computer, called the _____ was capable of assigning parts of a program to up to 256 different processors, thereby increasing processing speed and efficiency.

- A. NOVA
- B. Butterfly
- C. PDP-8
- D. Automatic Sequence Controlled Calculator (ASCC)

In 1984, the _____ personal computer was distributed by Apple Computer, Inc. It had a memory capacity of 128KB, an integrated monitor, and a mouse and was the first computer to legitimize the graphic interface. The computer presented users with graphic "icons", over-lapping graphic windows, and pull-down menus. The machine was plagued by limited memory and the lack of a hard drive but soon became a standard for graphic artists and publishers.

- A. first Reduced Instruction Set Computer (RISC)
- B. first Macintosh Computer
- C. first personal computer
- D. first computer to use the Intel 80286 microprocessor chip

In 1984, IBM distributed the IBM PC-AT, the _____. The Intel 80x86 series advanced the processor power and flexibility of the IBM computers. This computer also came with a new graphics system, EGA, that allowed 16 colors of graphics at higher resolutions (CGA, the earlier system only had four colors). The machine also incorporated a 16-bit data bus that allowed for the creation of more sophisticated expansion cards.

- A. first Reduced Instruction Set Computer (RISC)
- B. first Macintosh Computer
- C. first personal computer
- D. first computer to use the Intel 80286 microprocessor chip

APPENDIX B
ALBUM OF SCREEN GRAPHICS

The History of Computers – Storyboard

Figure 5. The HTML entrance to the research page.

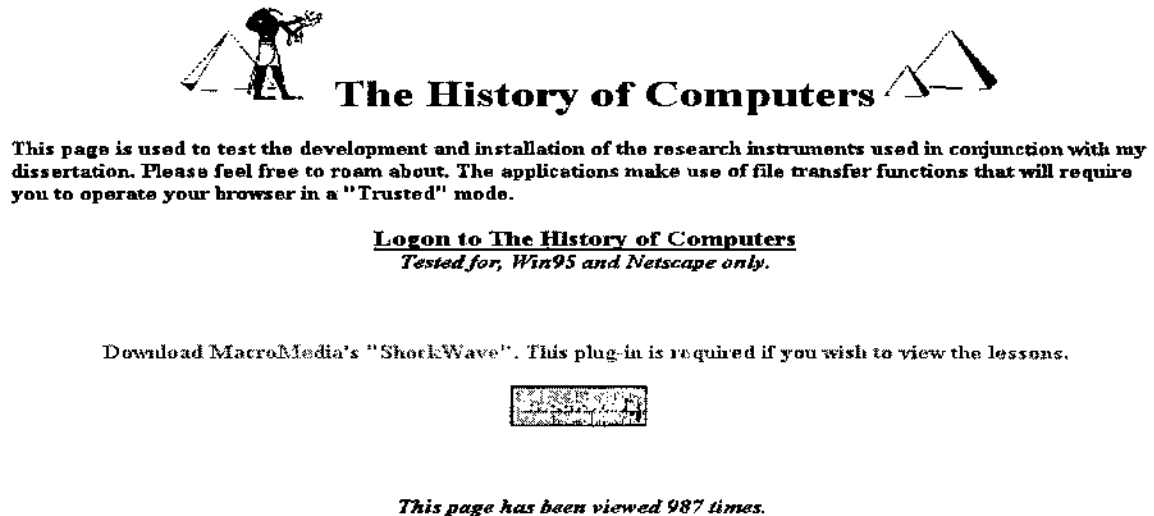


Figure 6. The Shockwave Authorware Security Screen

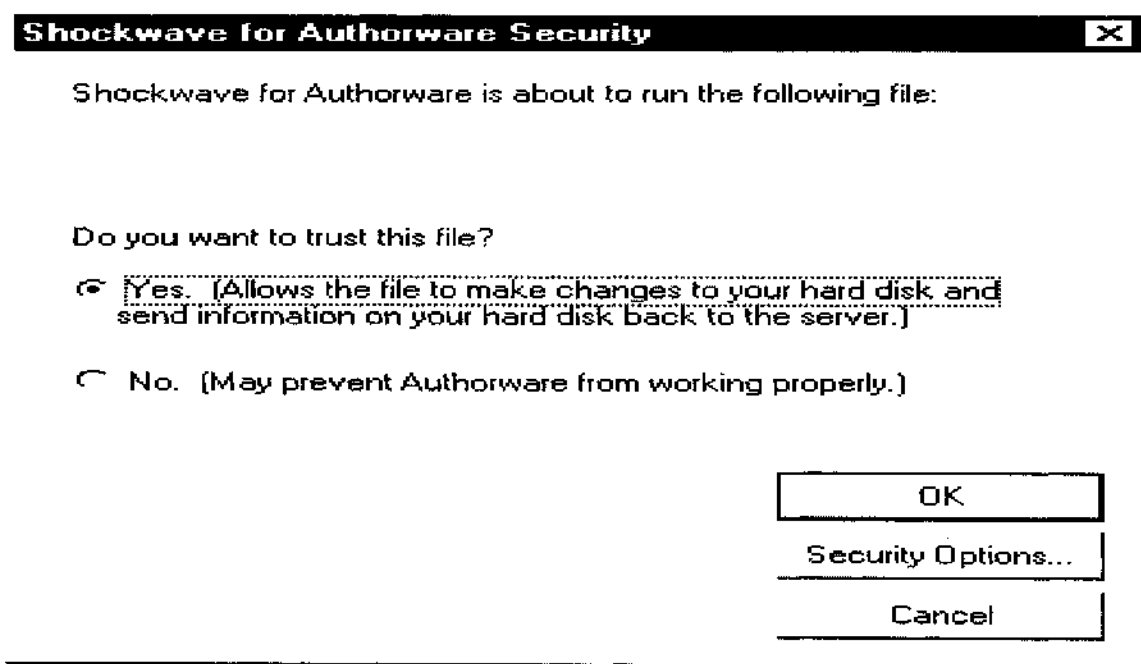


Figure 7. The E-Mail Reporting Screen

The screenshot shows a Netscape browser window with the following elements:

- Browser Title Bar:** Netscape
- Menu Bar:** File Edit View Go Bookmarks Options Directory Window Help
- Location Bar:** Location: []
- Navigation Buttons:** FlashNet | News | Mail | CNN Online | Net Search | Personal
- Main Content Area:**
 - Decorative graphics of a person climbing a pyramid on the left and right.
 - Thank You !** (Large centered text)
 - If you wish, here is an opportunity to make any comments or requests. Your participation in this research is greatly appreciated.**
 - Form fields:
 - Please send me a copy of my participation in the study:
 - Please send me the results of the study:
 - Your Name: []
 - Your E-mail: []
 - Comments & Requests** (Section header)
 - Large empty text area for comments.
 - Buttons:
- Status Bar:** Document Done

Figure 8. The Login Screen

The screenshot shows a 'Presentation Window' with the following elements:

- Window Title Bar:** Presentation Window
- Navigation Buttons:** Exit to HomePage | Overview Help
- Main Content Area:**
 - The History of Computers** (Large centered title)
 - Text: **If this is the first time for you to login please take a moment to read the Overview section and get to know more about the features of this application.**
 - Text: **After you complete all of the lessons and associated activities you will have an opportunity to receive the results of your interactions and a soft copy of the Dissertation.**
 - Text: **Thank you for your interest in becoming part of this research project.**
 - Buttons:
 - Decorative graphics of a person climbing a pyramid on the left and right.
 - HOME** button with a house icon in the bottom right corner.

Figure 9. The User Identification and Password Screen

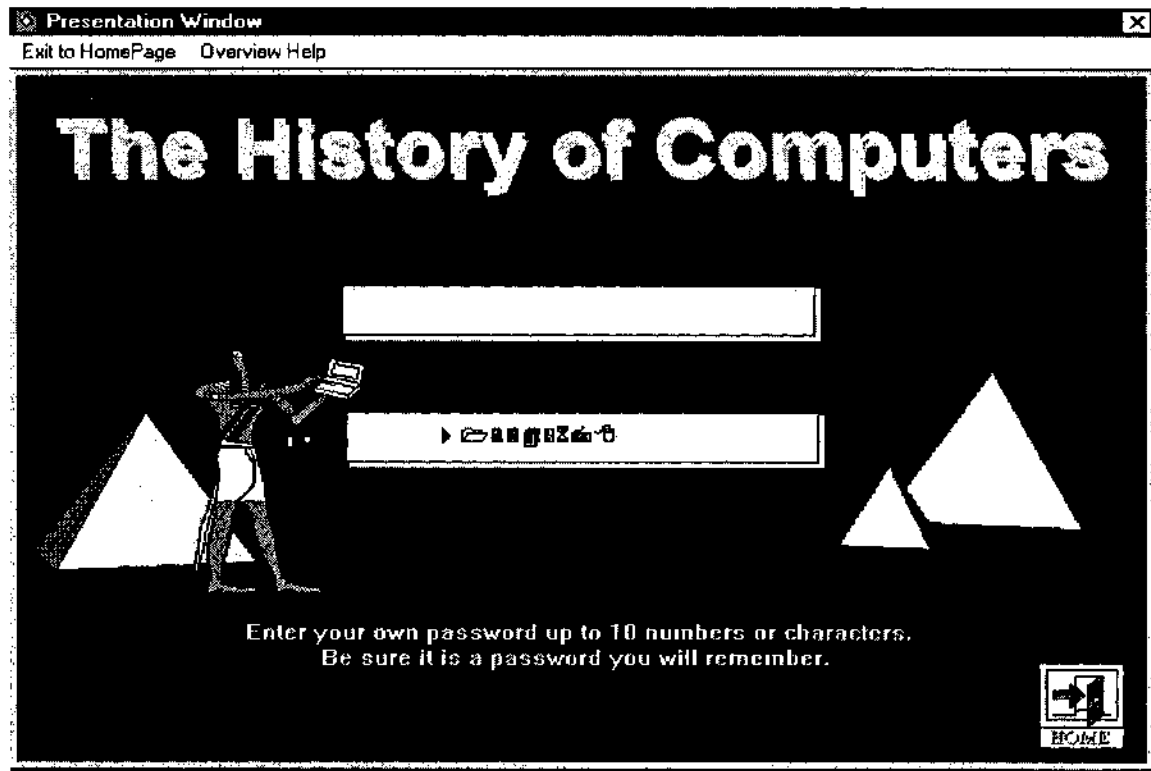


Figure 10. The Demographics Sign-On Screen

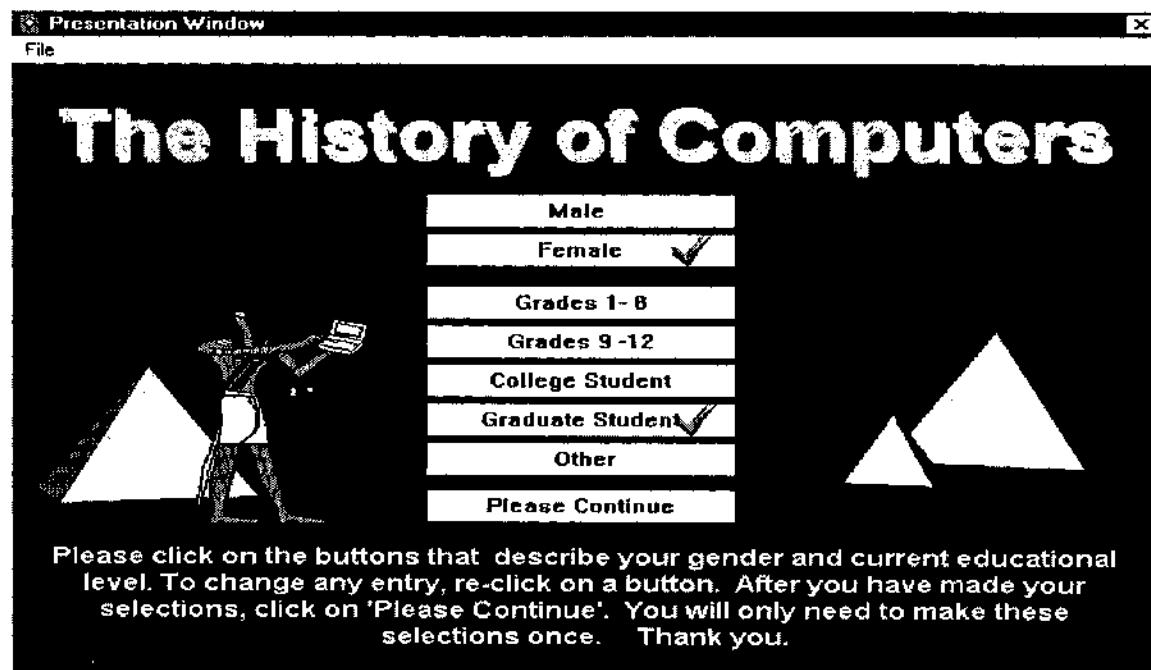


Figure 11. The Main menu Screen

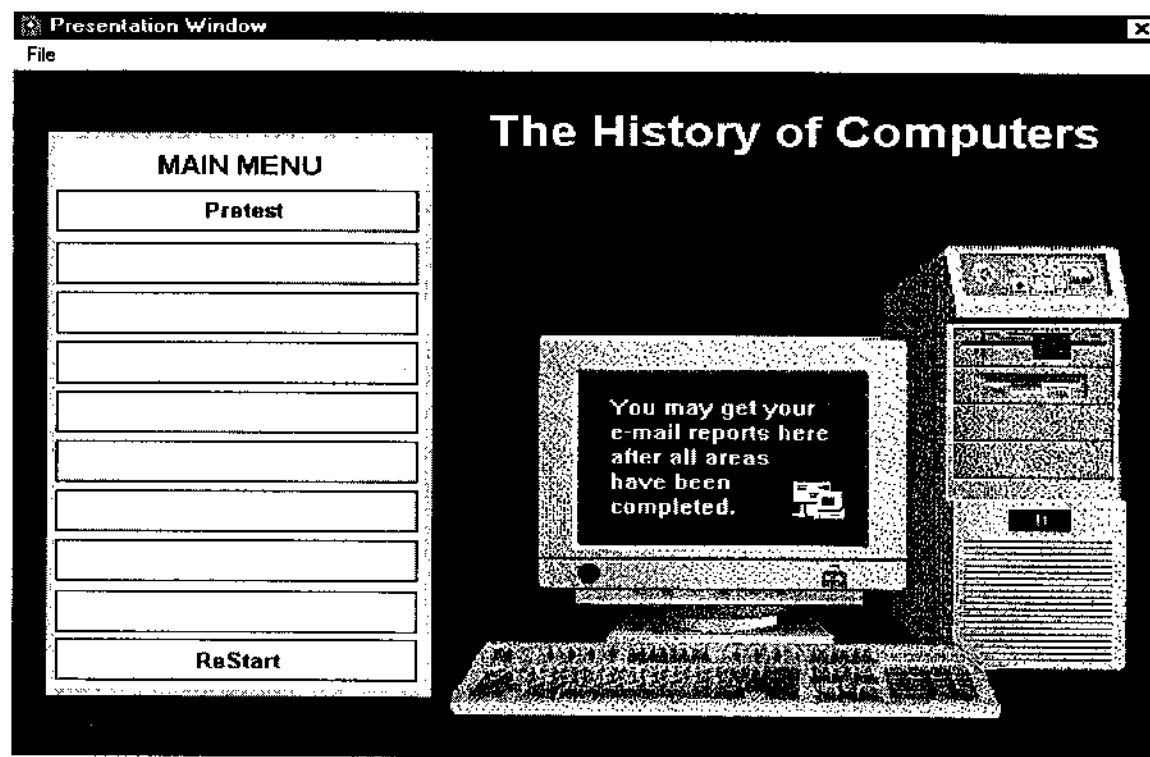


Figure 12. An Introduction To A Lesson Screen

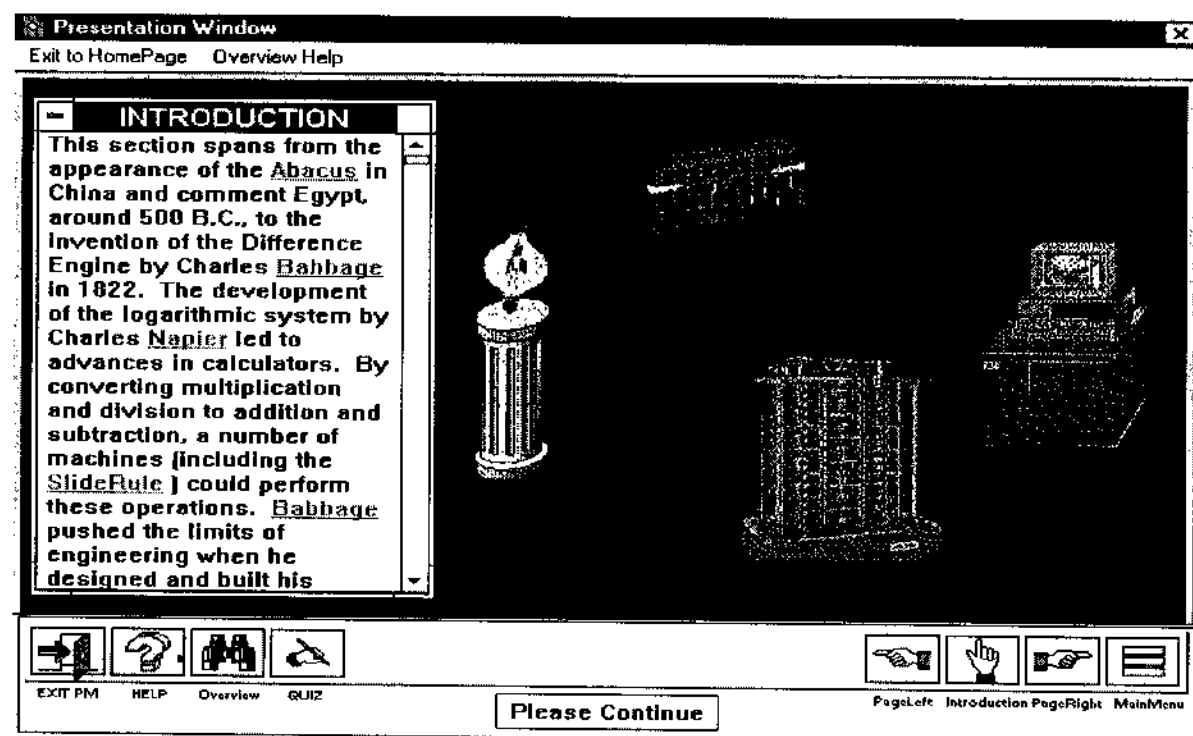


Figure 13. A Glossary Menu

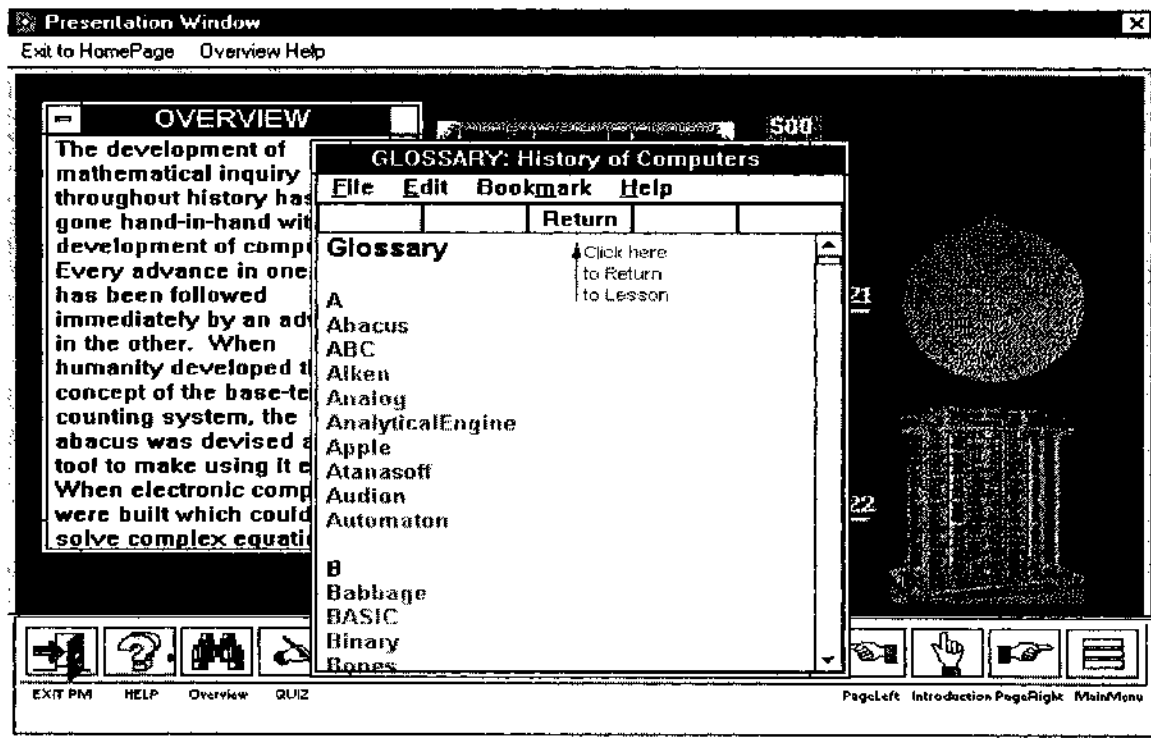


Figure 14. A Pop Up Help Screen

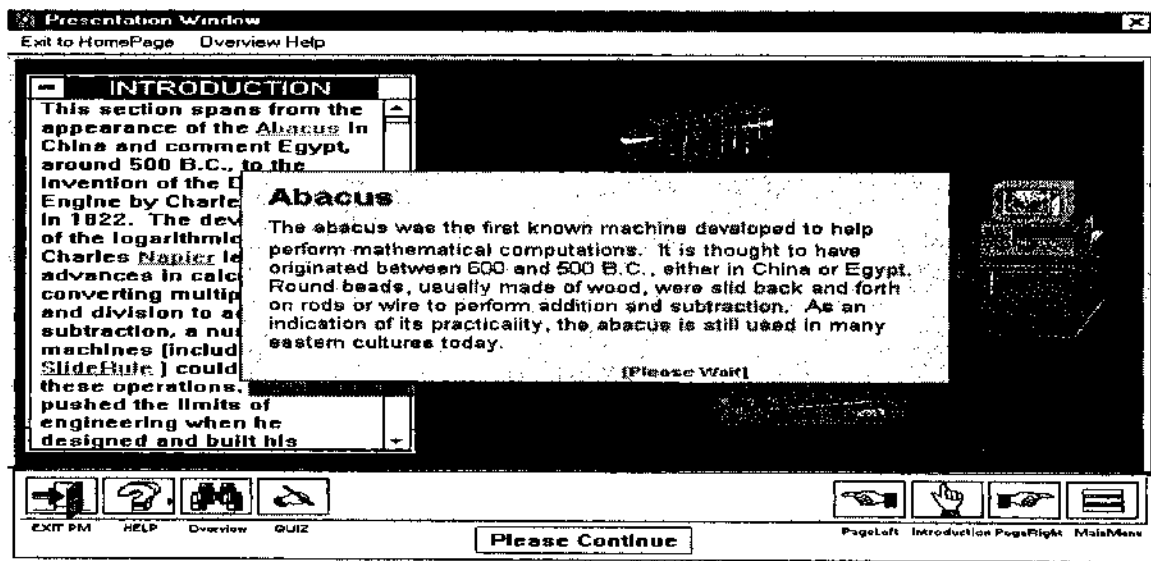


Figure 15. A Lesson Screen

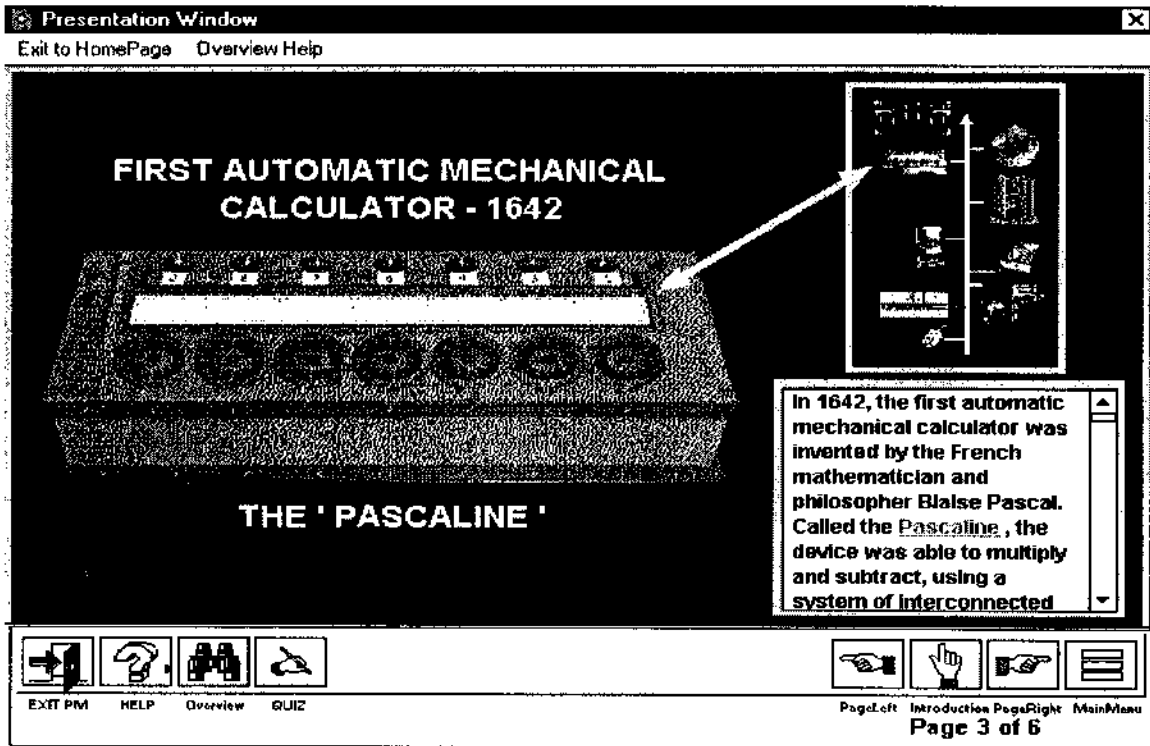


Figure 16. A practice Quiz Screen

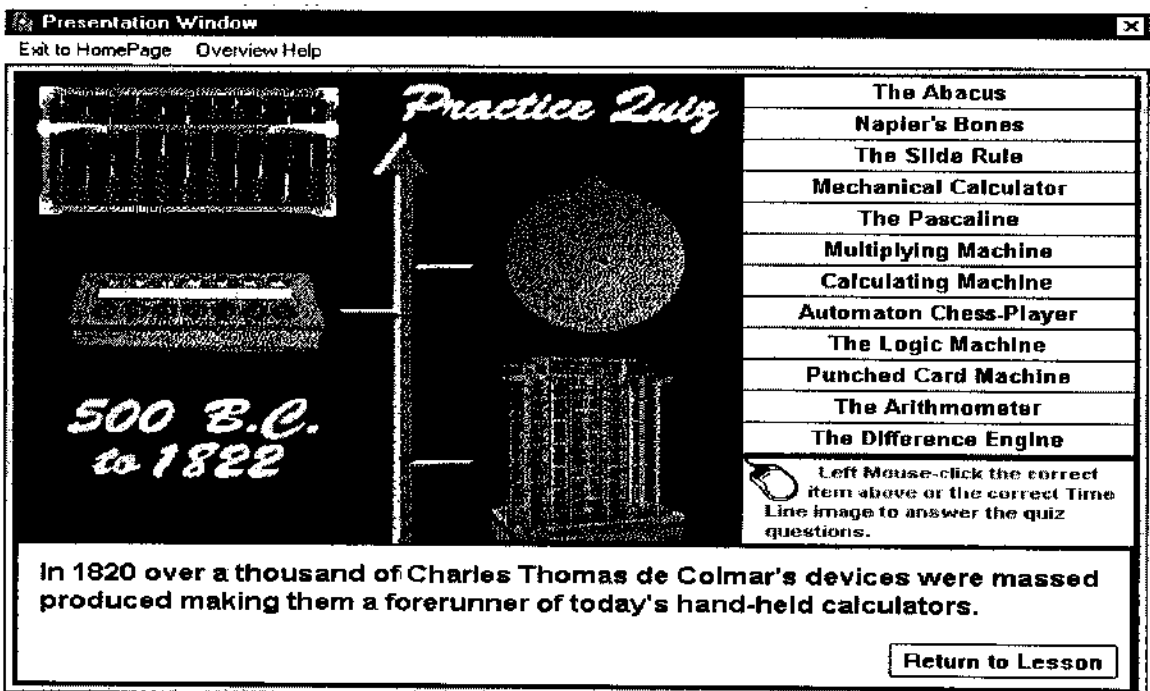


Figure 17. The Overview Screen (Focused)

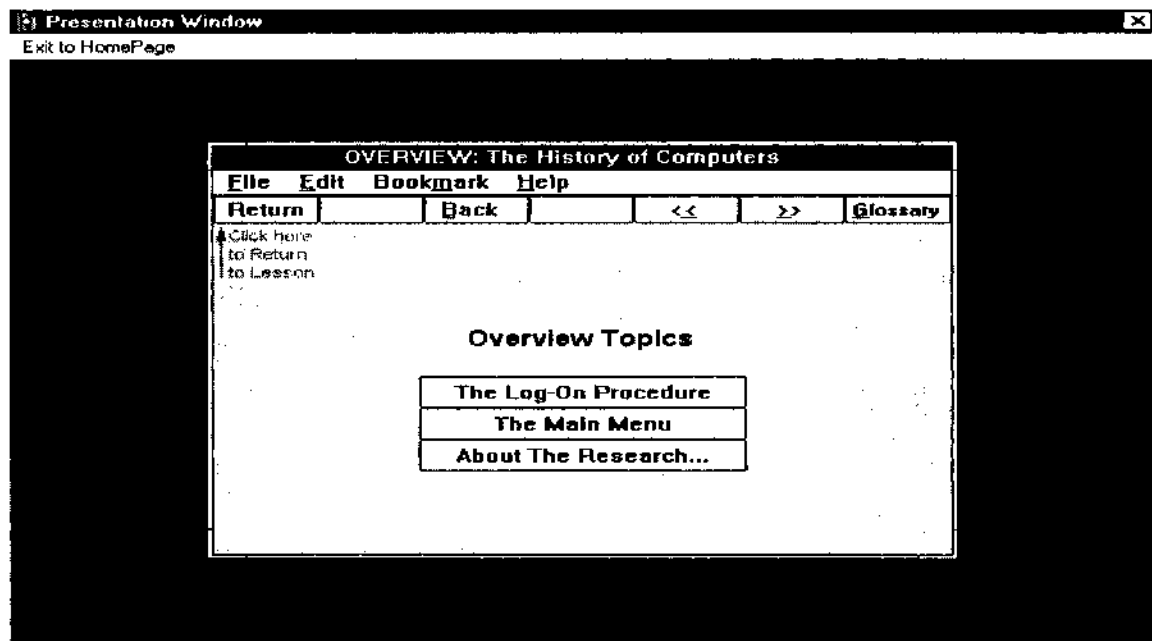


Figure 18. The Log-On Overview Screen (Focused)

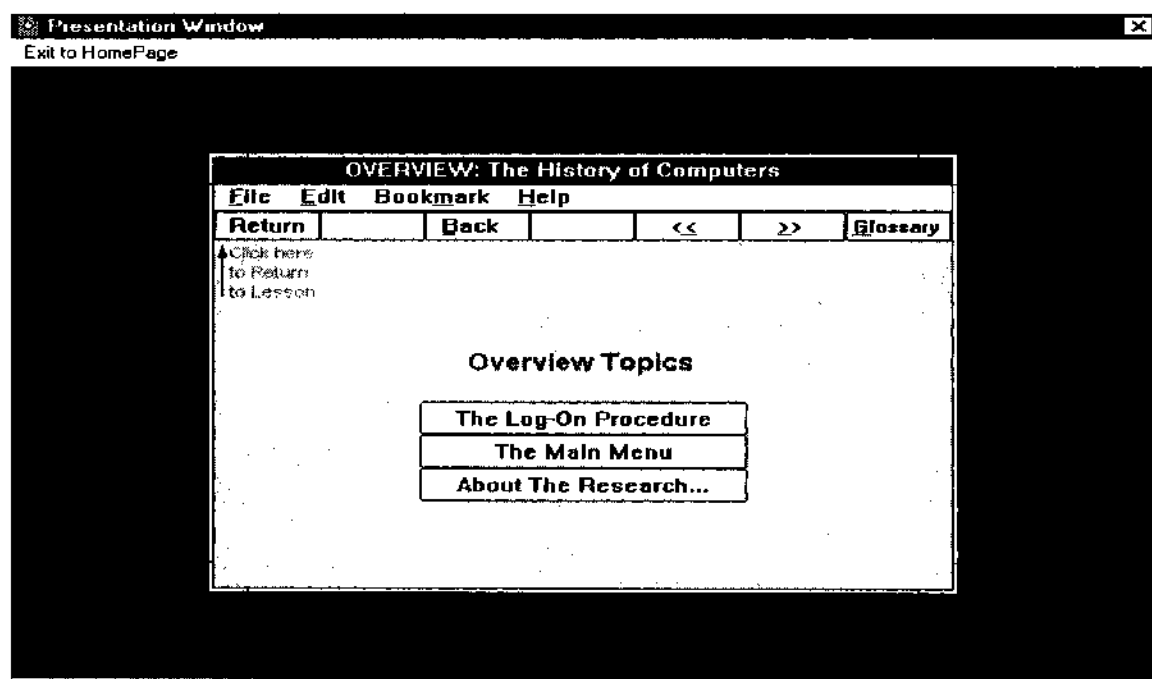


Figure 19. The Pre-Test, Posttest and Likert-Like Overview Screen (Focused)

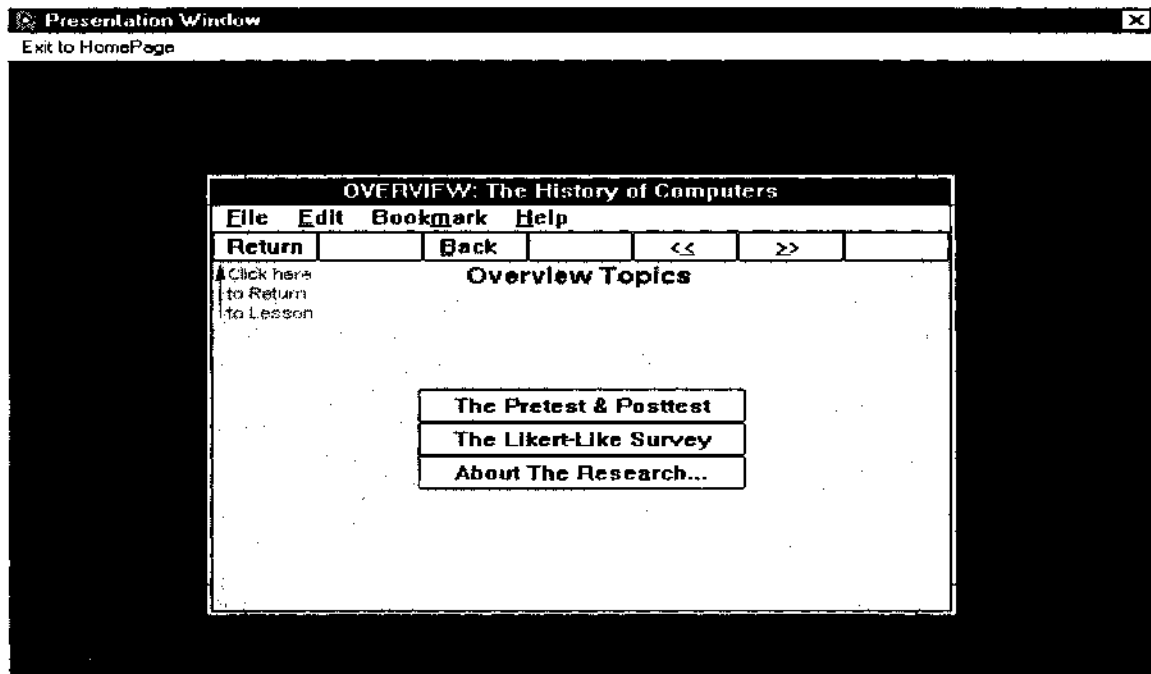


Figure 20. The Lesson Overview Screen (Focused)

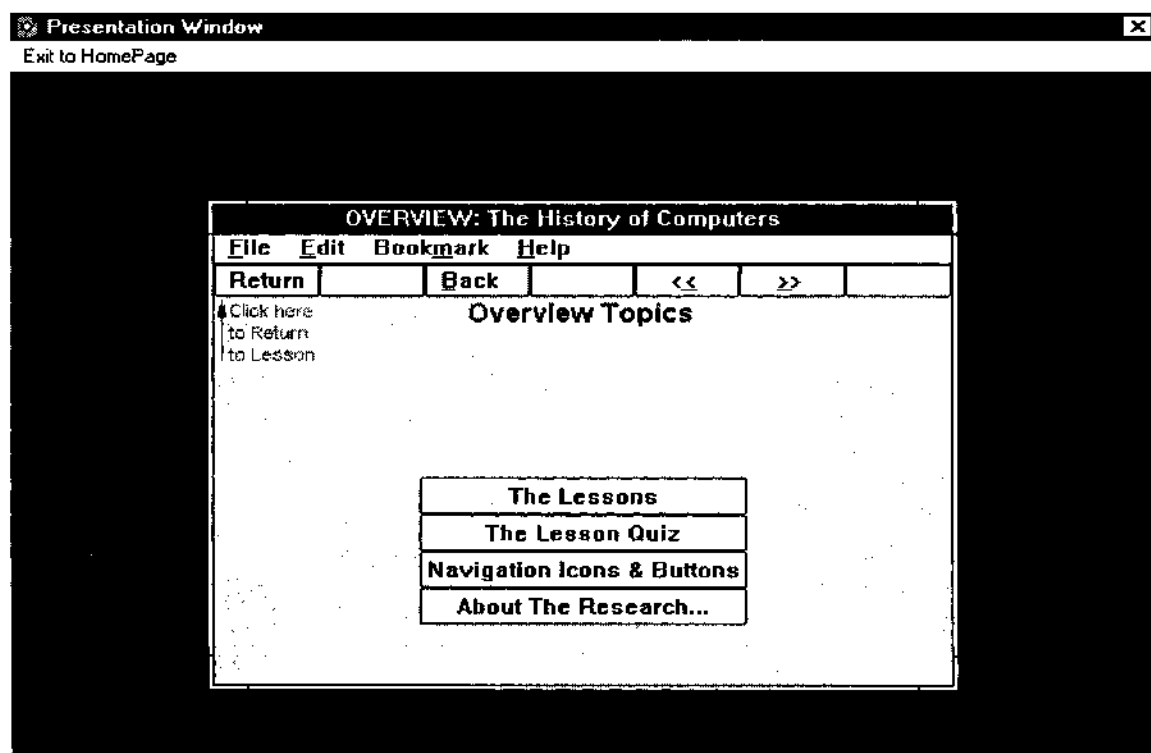


Figure 21. The Test and Survey Overview Screen (Focused)

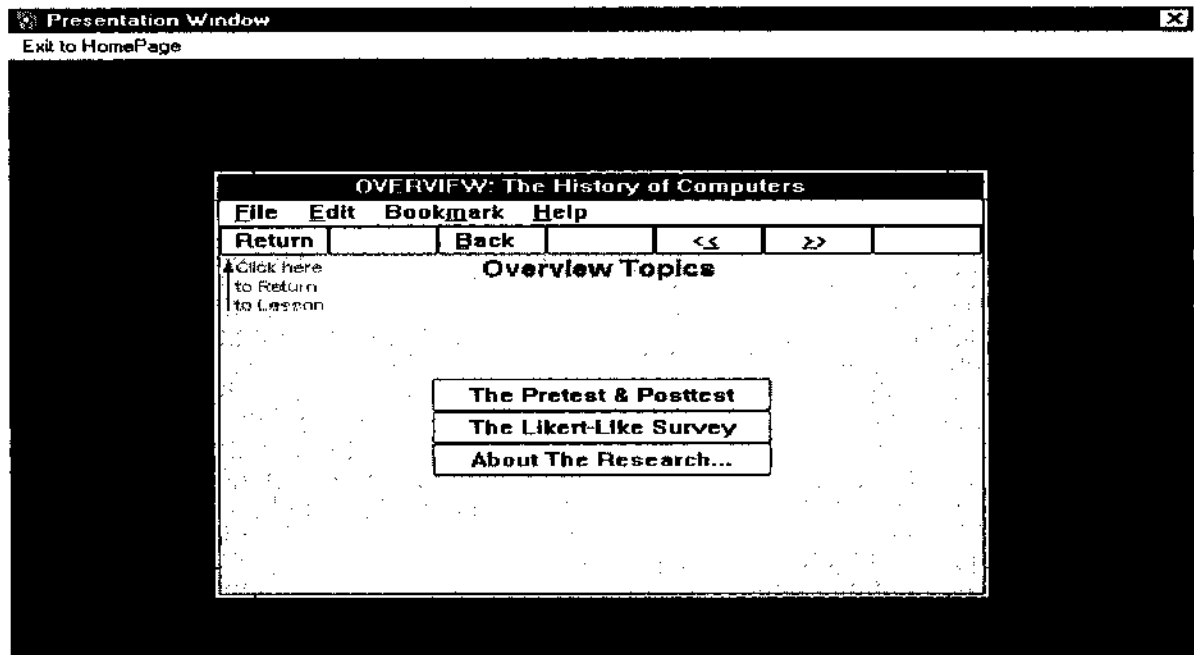


Figure 22. The Overview Screen (Unfocused)

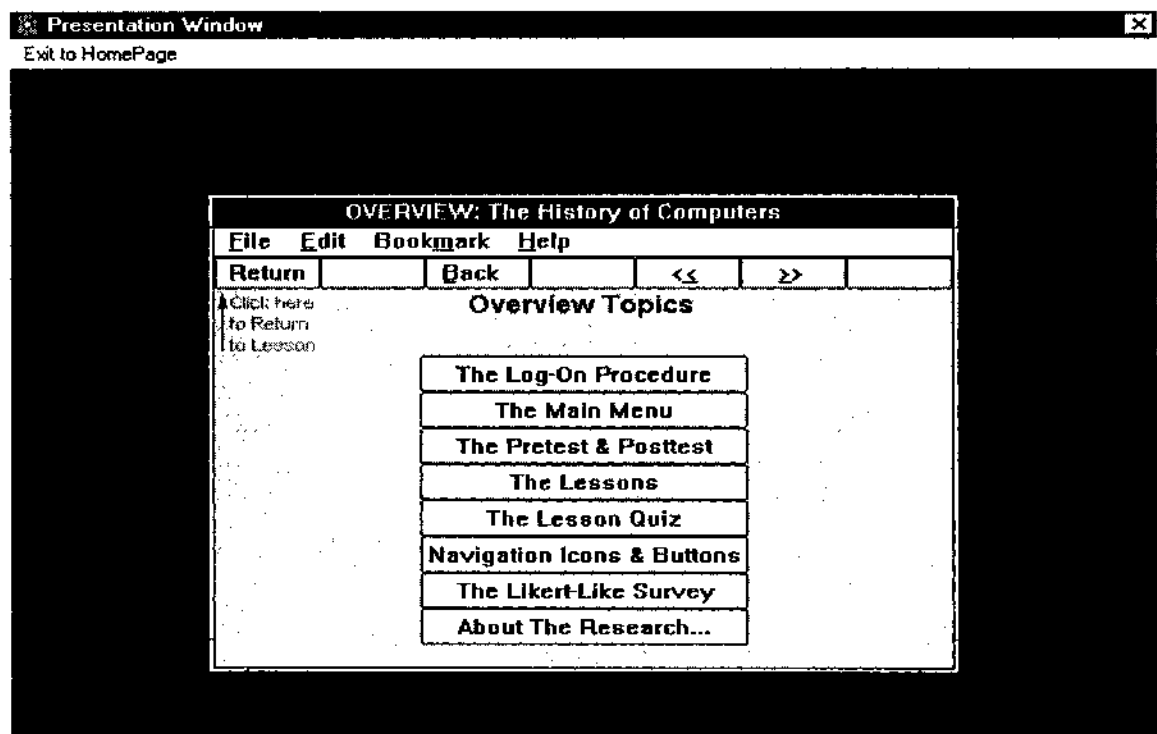


Figure 23. Overview: The Log-On Procedure – Screen 0 of 3

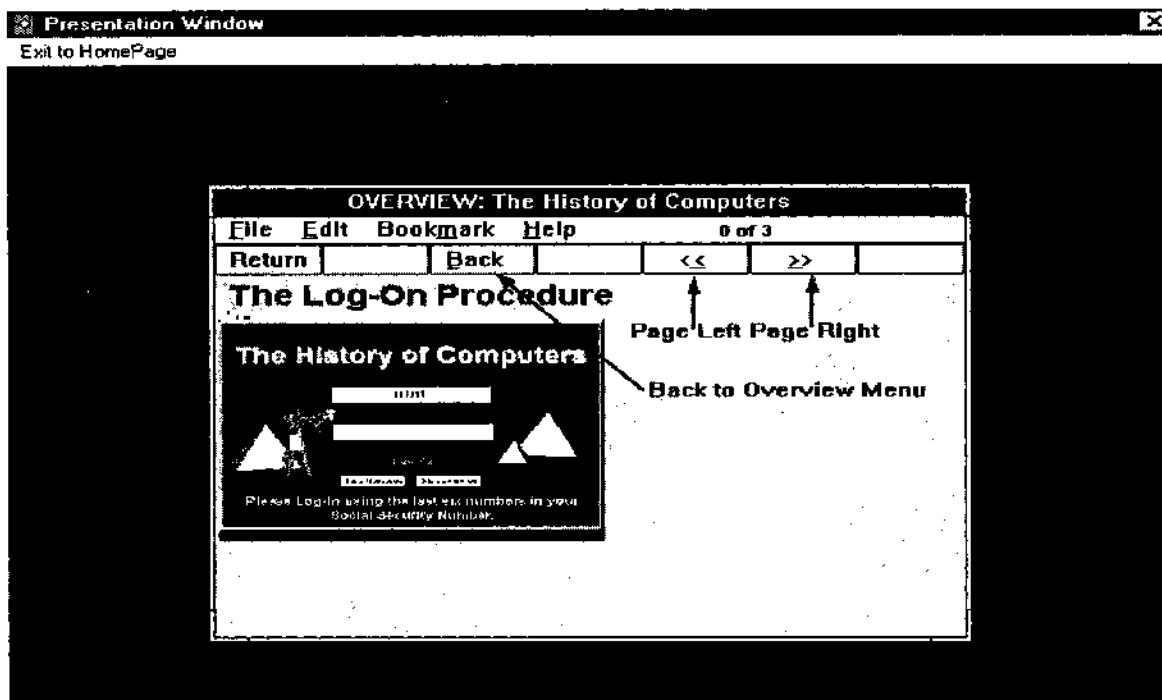


Figure 24. Overview: The Log-On Procedure – Screen 1 of 3

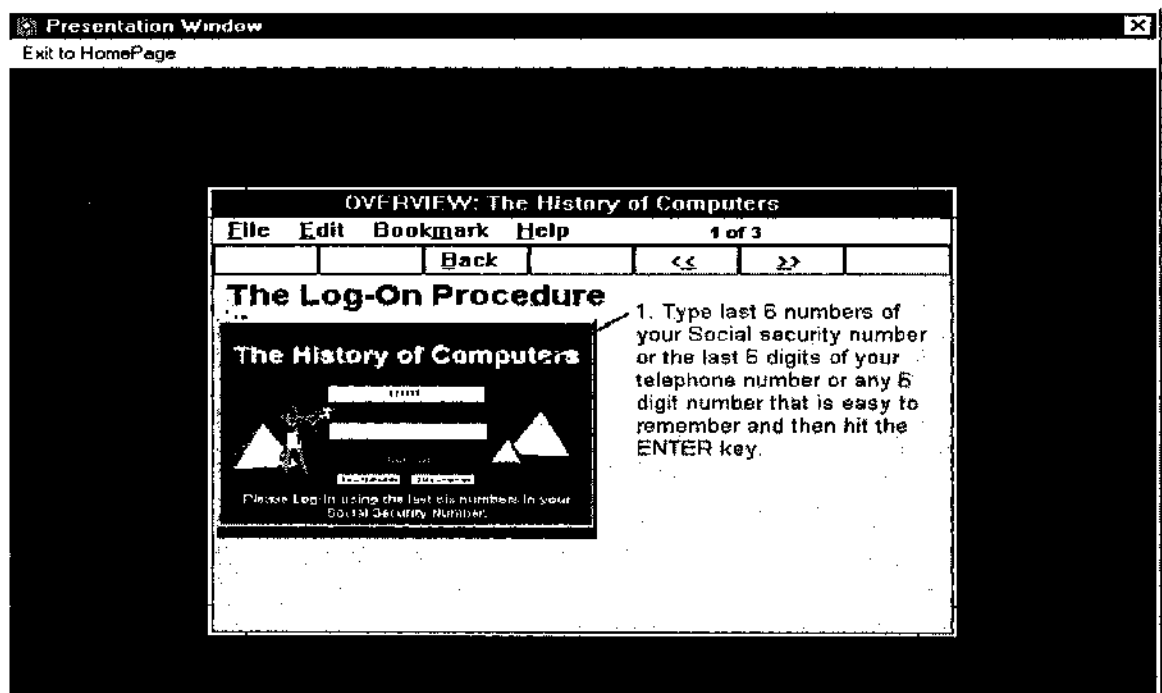


Figure 25. Overview: The Log-On Procedure – Screen 2 of 3

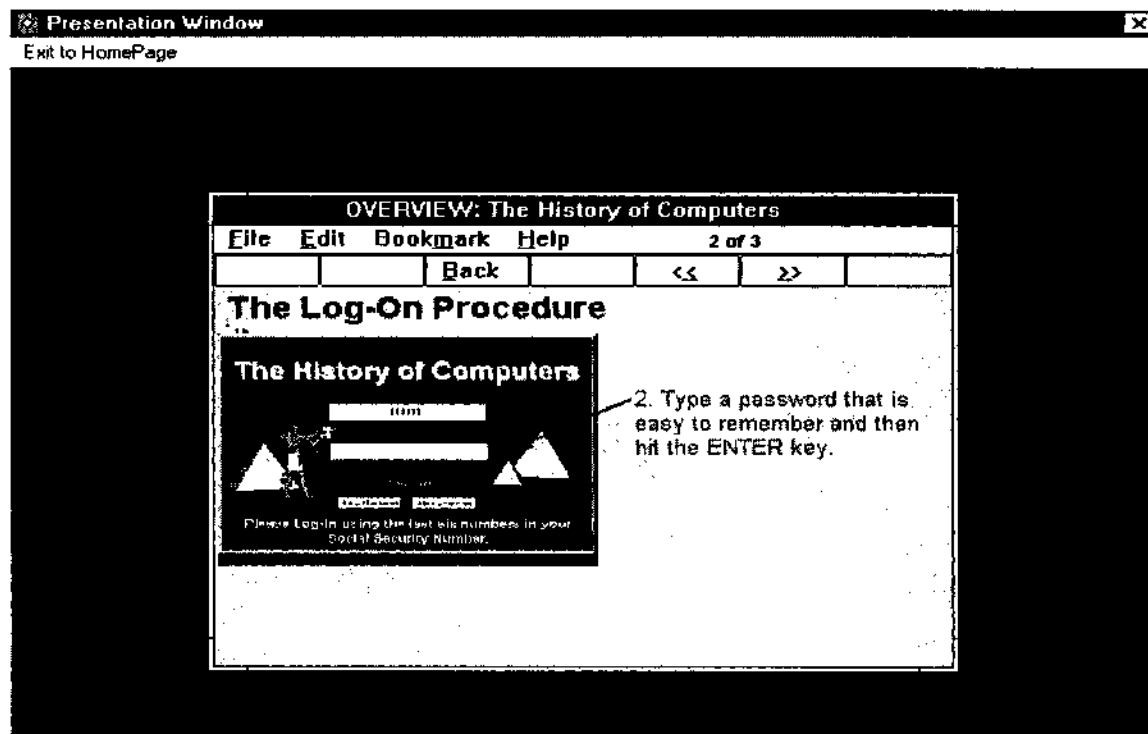


Figure 26. Overview: The Log-On Procedure – Screen 3 of 3

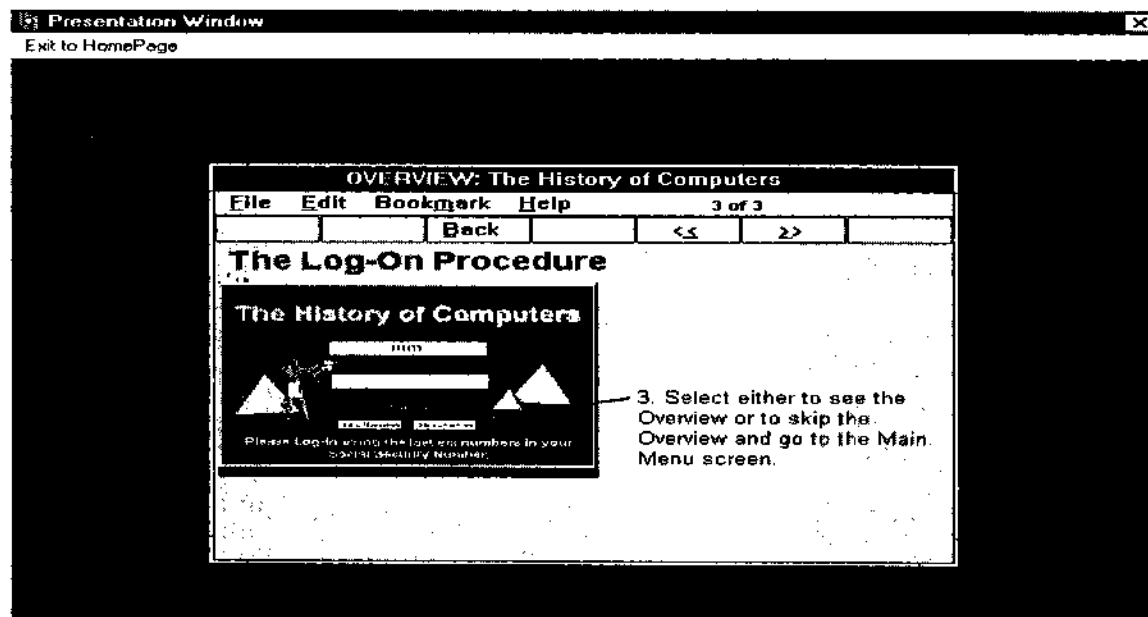


Figure 27. Overview: The Main Menu – Screen 0 of 5

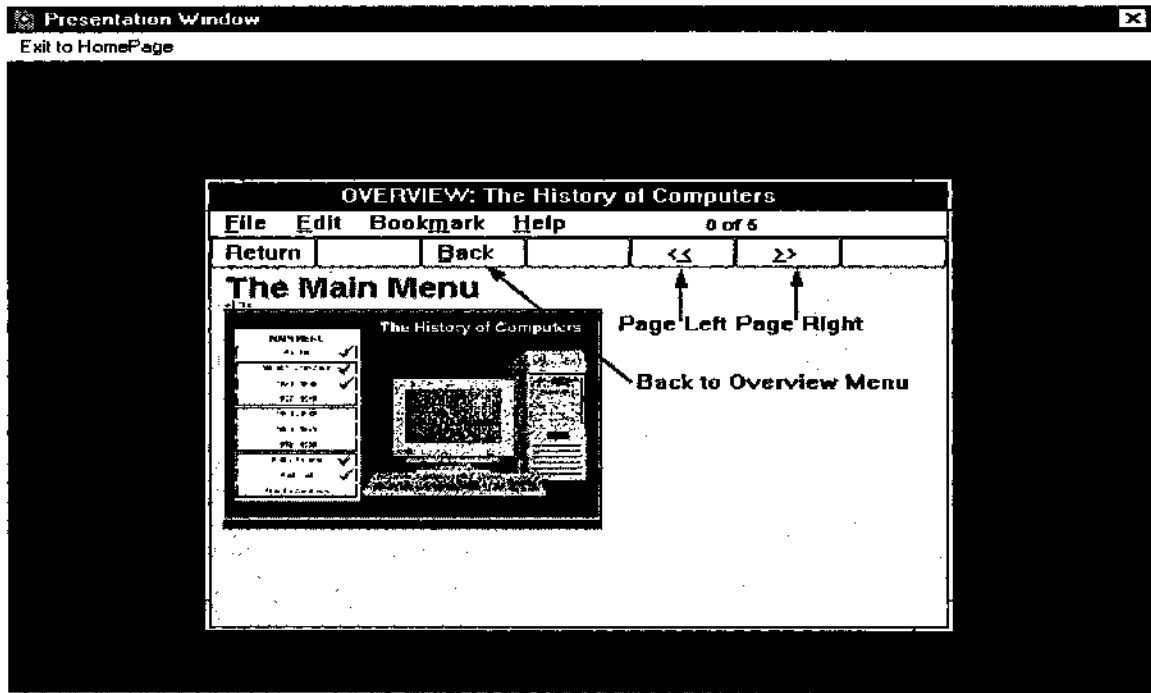


Figure 28. Overview: The Main Menu – Screen 1 of 5

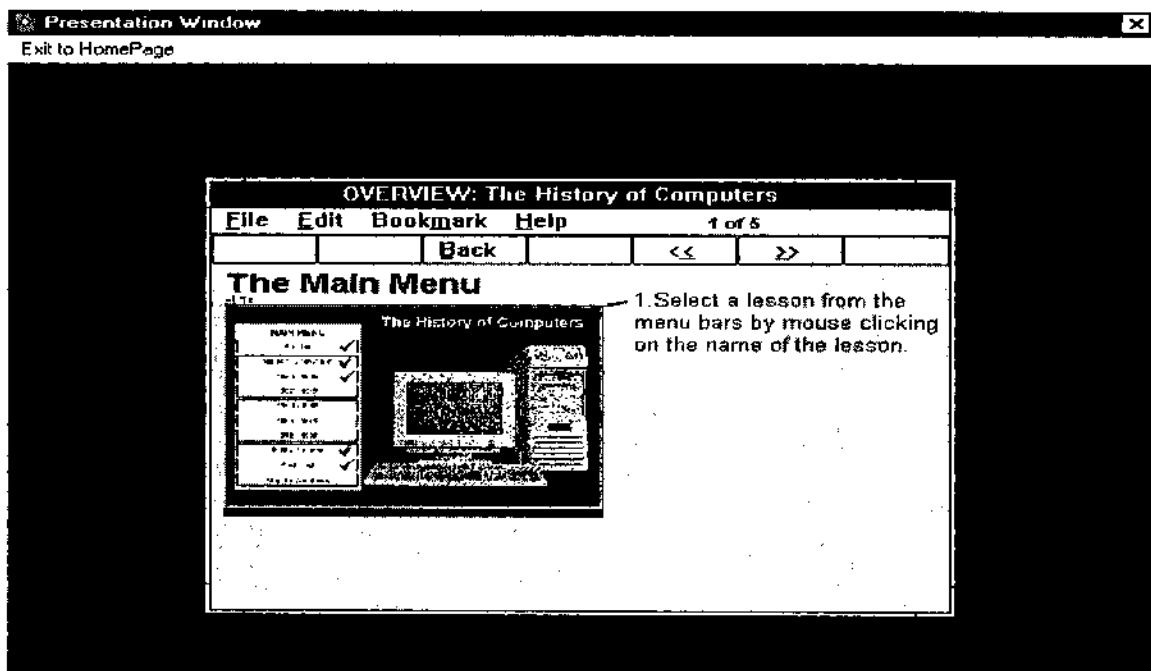


Figure 29. Overview: The Main Menu – Screen 2 of 5

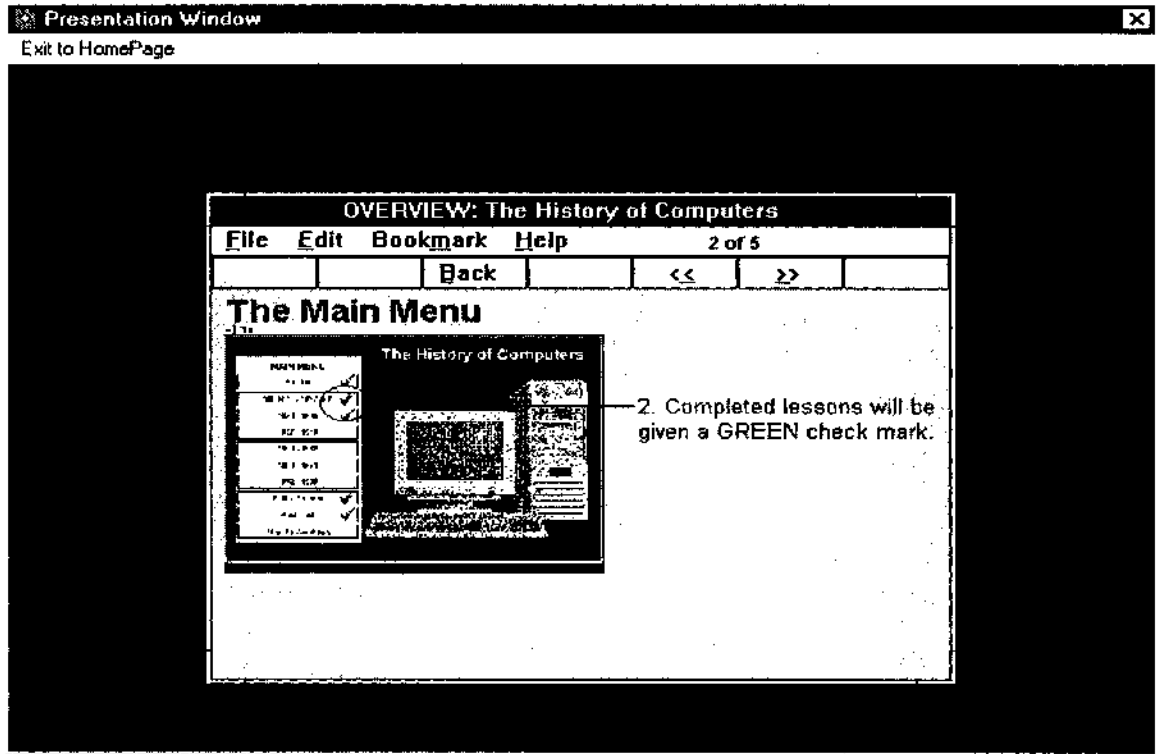


Figure 30. Overview: The Main Menu – Screen 3 of 5

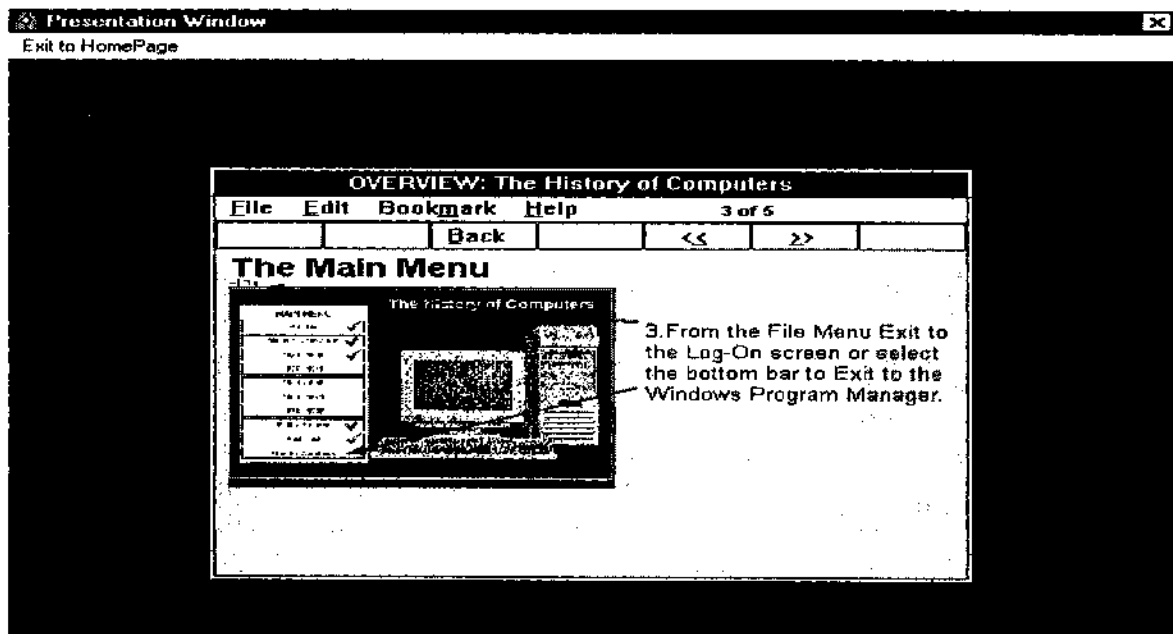


Figure 31. Overview: The Main Menu – Screen 4 of 5

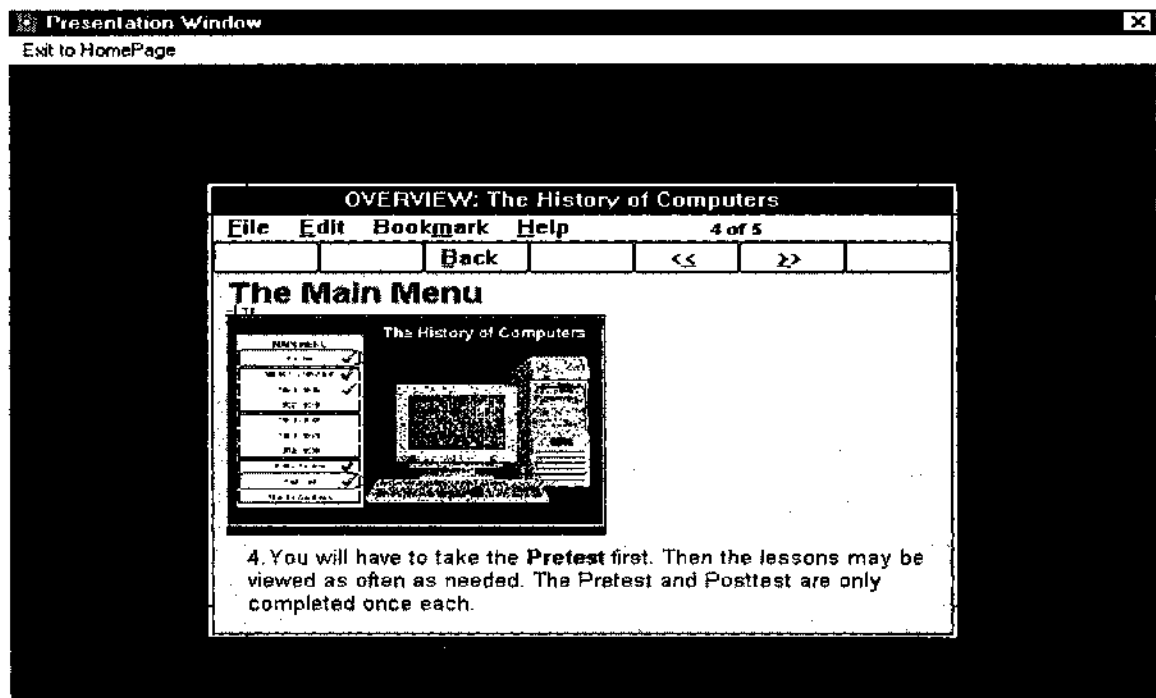


Figure 32. Overview: The Main Menu – Screen 5 of 5

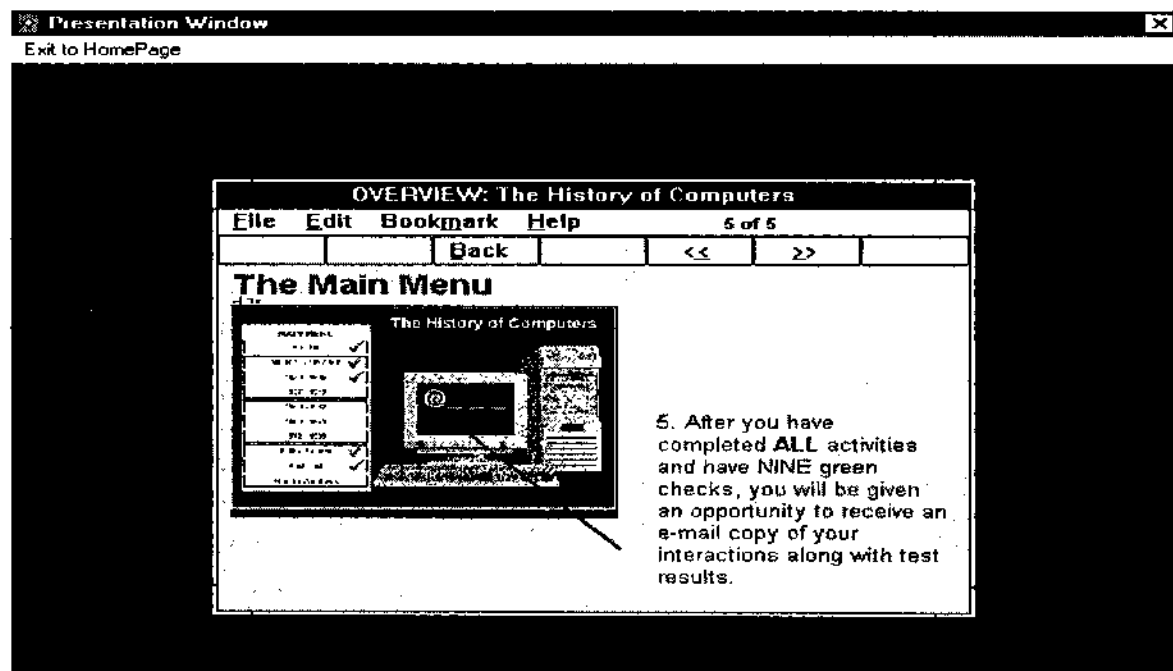


Figure 33. Overview: Pre-test and Posttest Screen 0 of 5

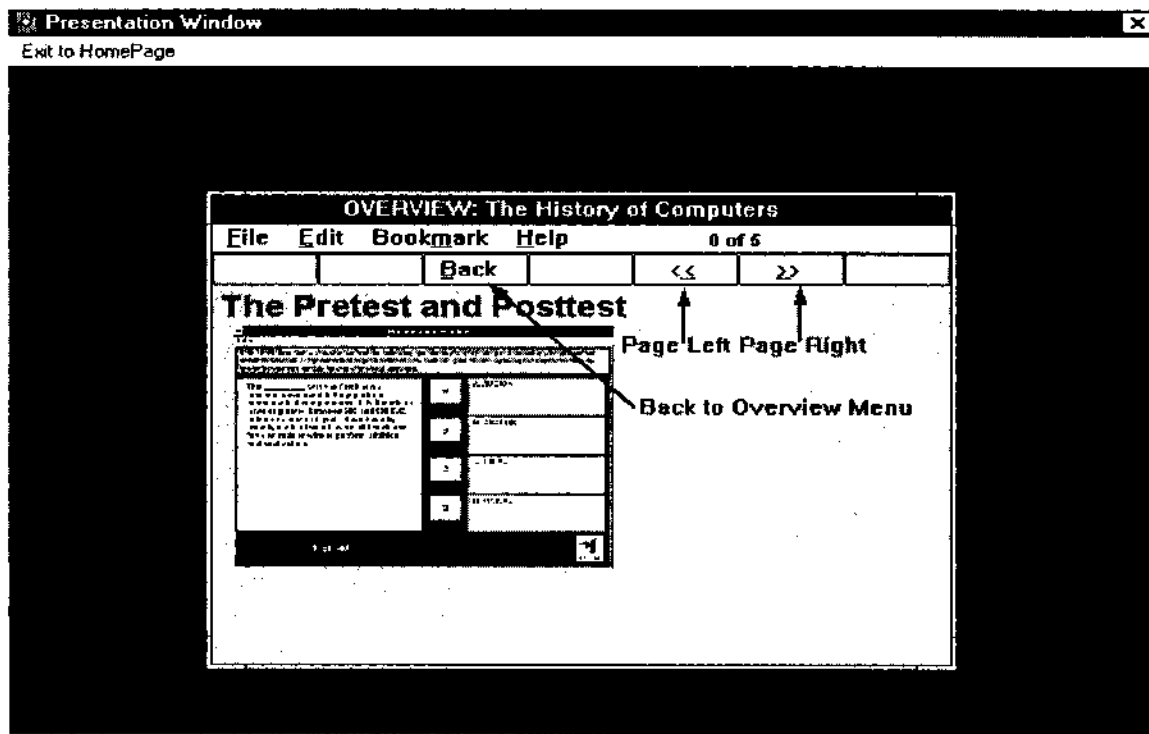


Figure 34. Overview: Pre-test and Posttest Screen 1 of 5

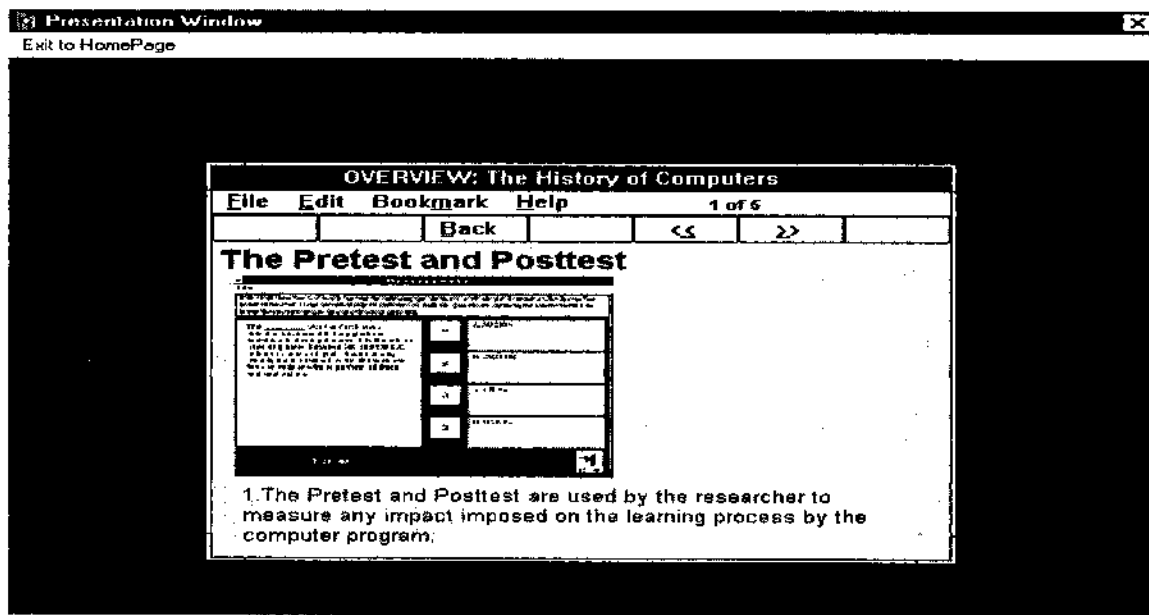


Figure 35. Overview: Pre-test and Posttest Screen 2 of 5

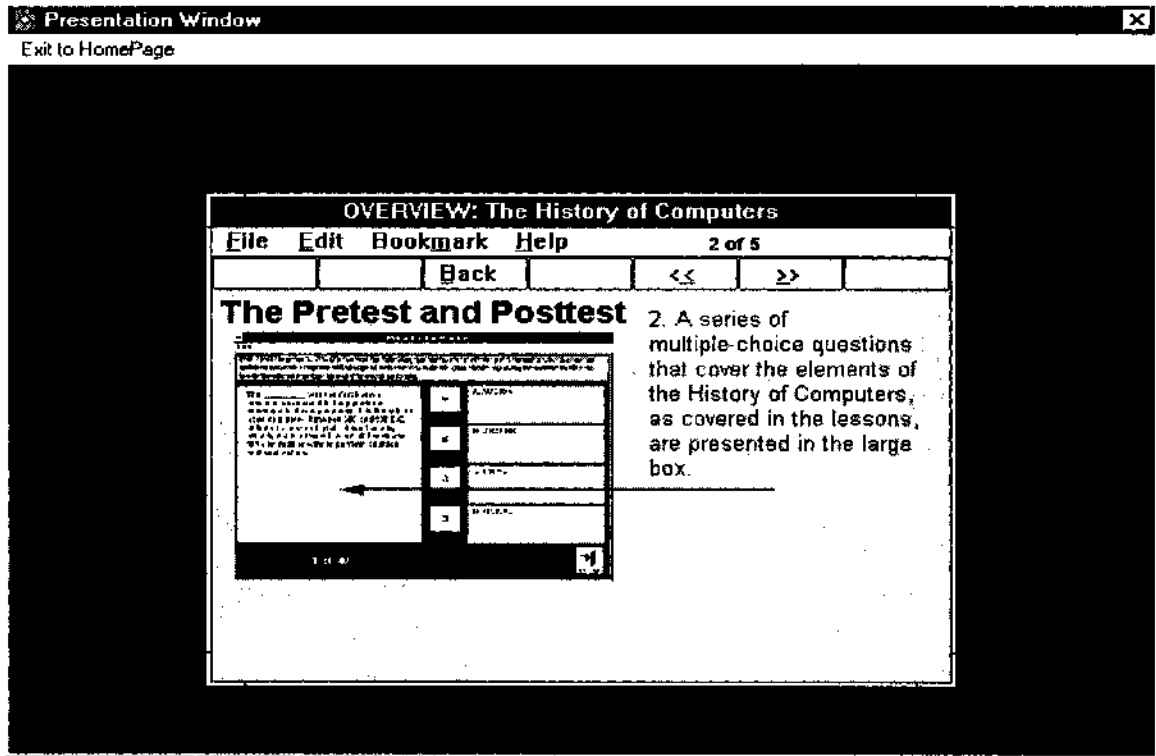


Figure 36. Overview: Pre-test and Posttest Screen 3 of 5

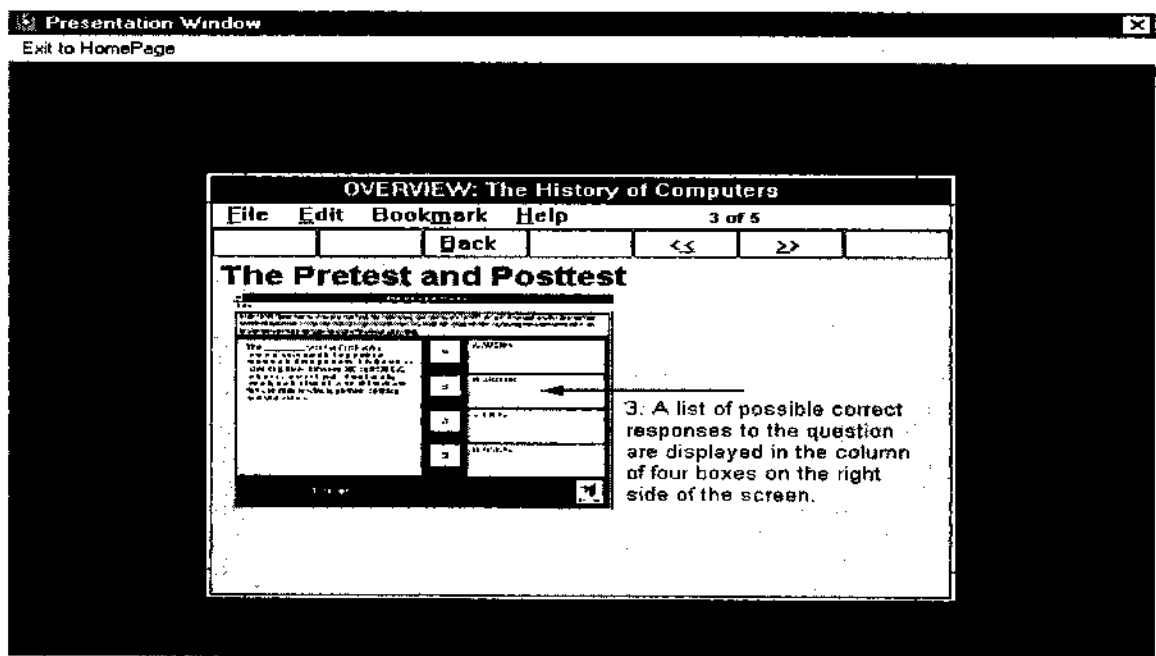


Figure 37. Overview: Pre-test and Posttest Screen 4 of 5

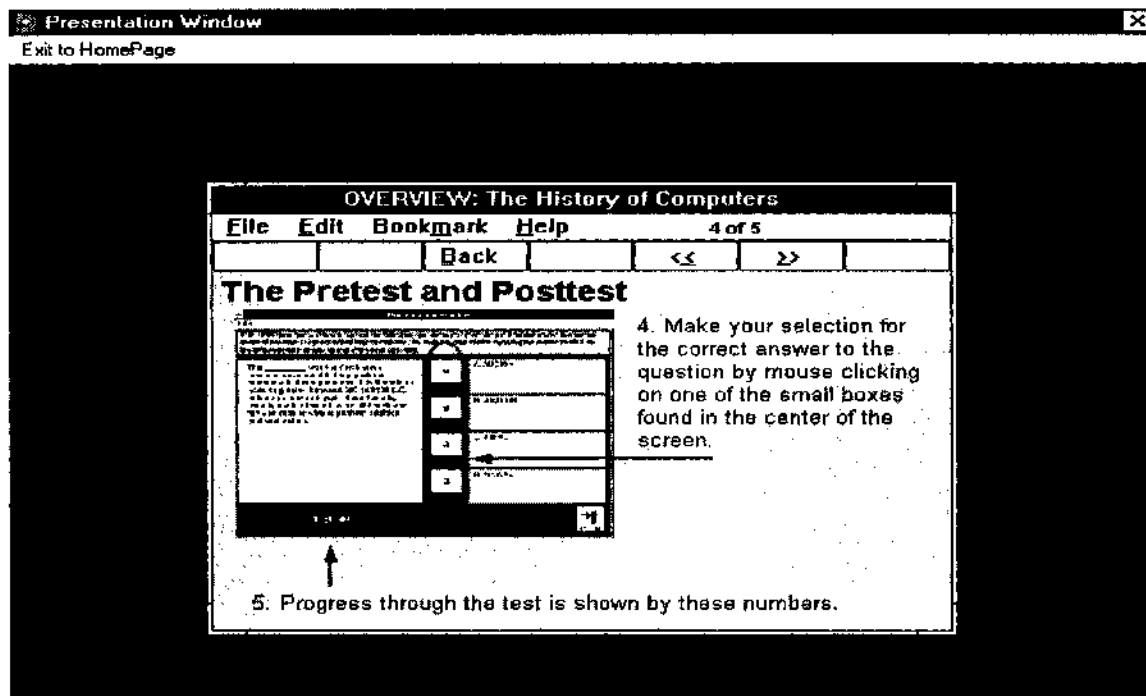


Figure 38. Overview: Pre-test and Posttest Screen 5 of 5

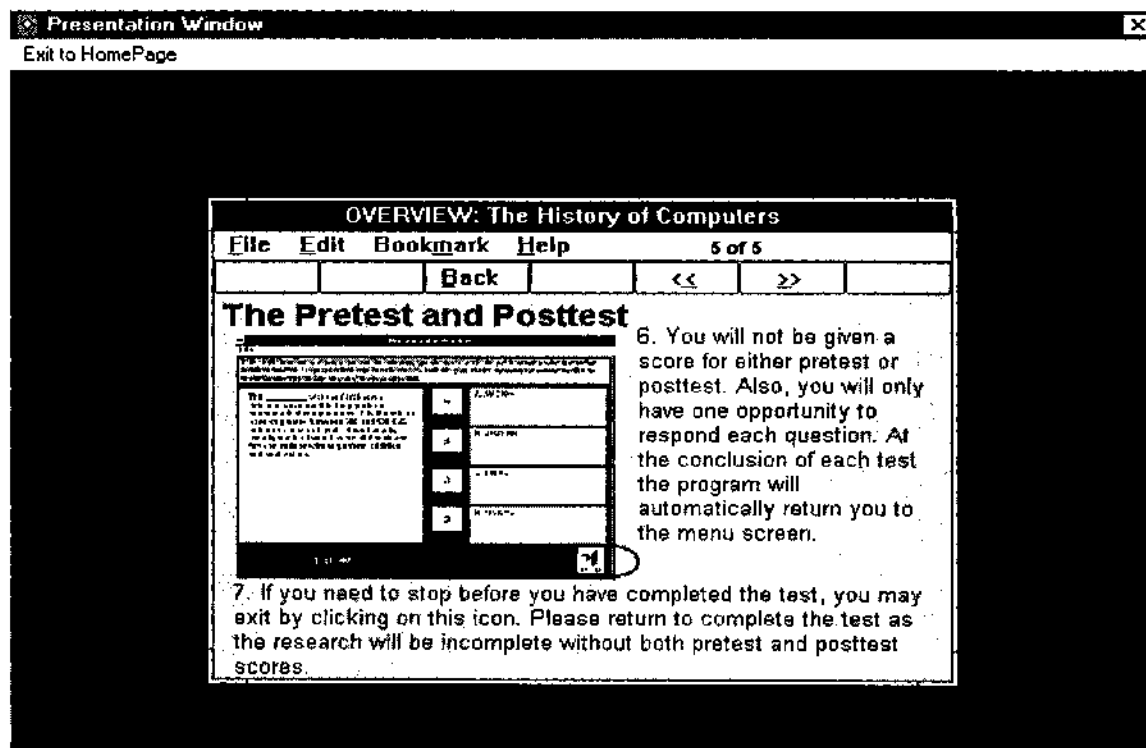


Figure 39. Overview: The Lessons Screen 0 of 5

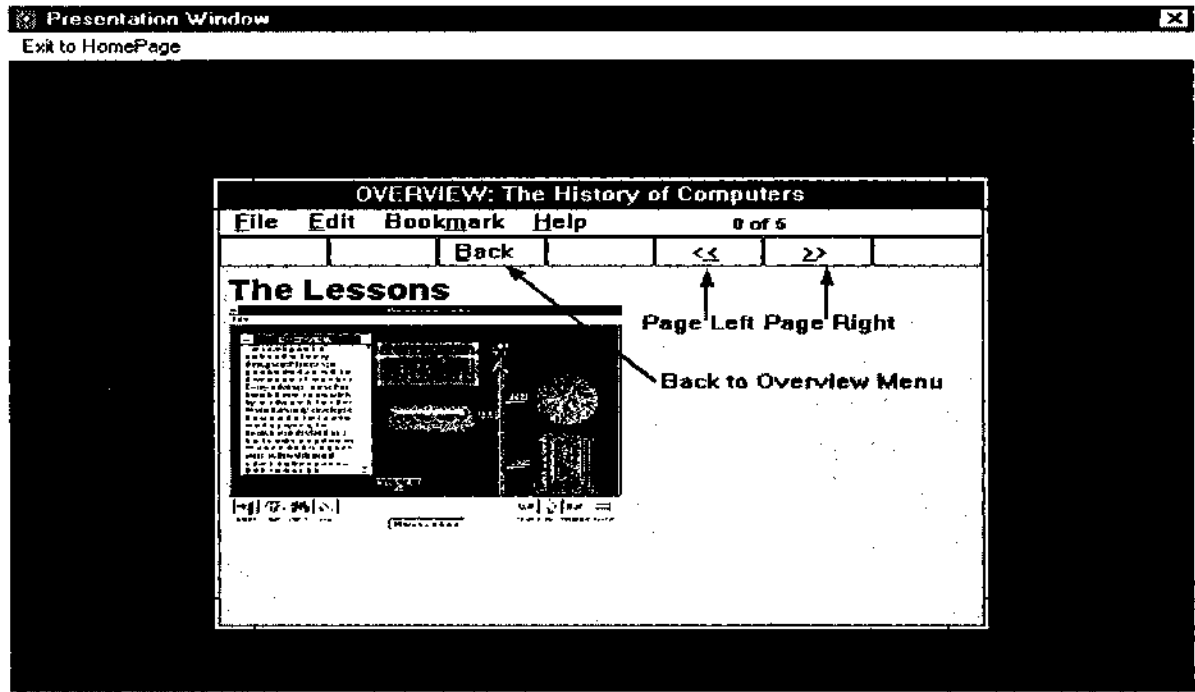


Figure 40. Overview: The Lessons Screen 1 of 5

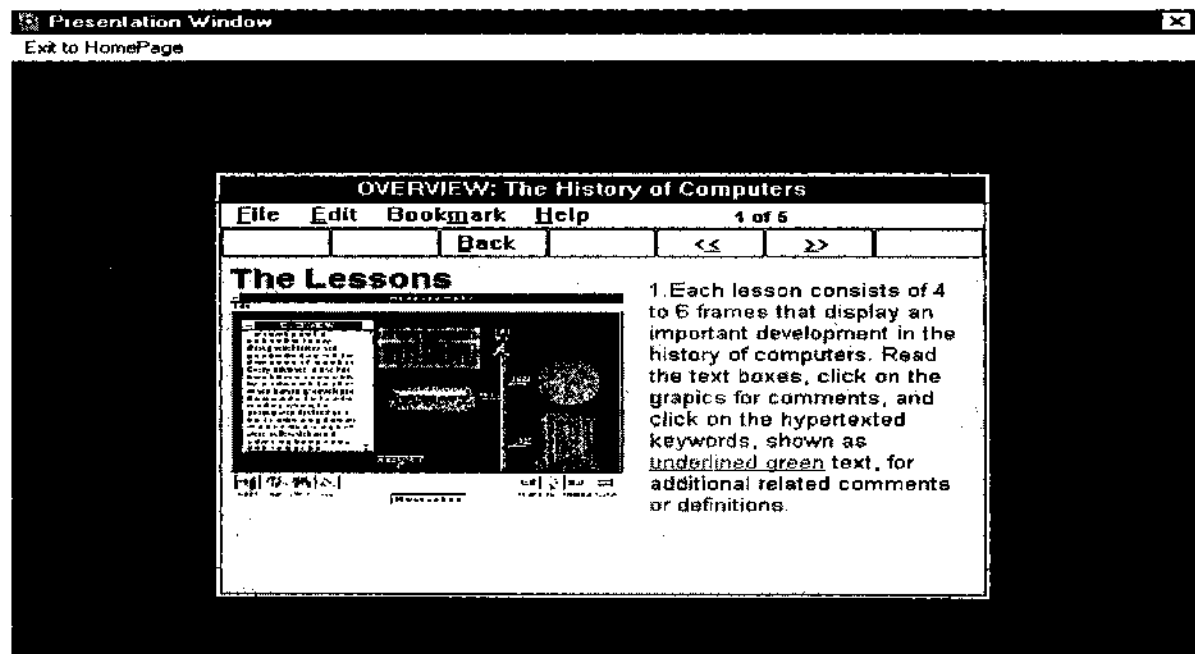


Figure 41. Overview: The Lessons Screen 2 of 5

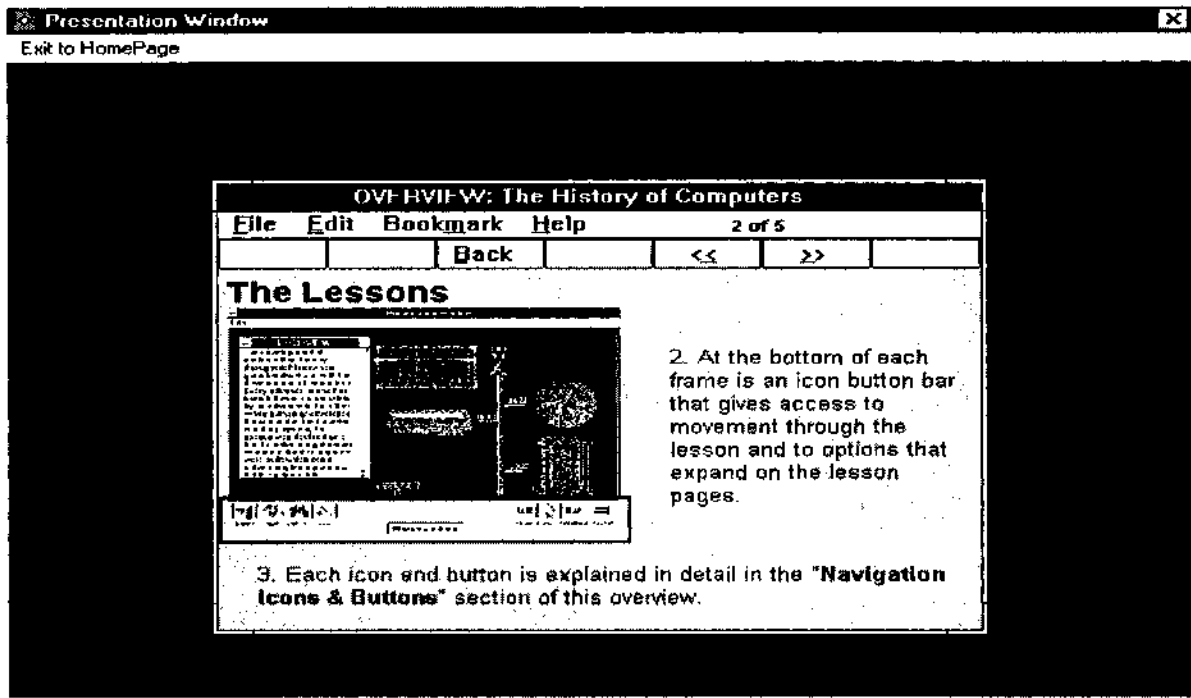


Figure 42. Overview: The Lessons Screen 3 of 5

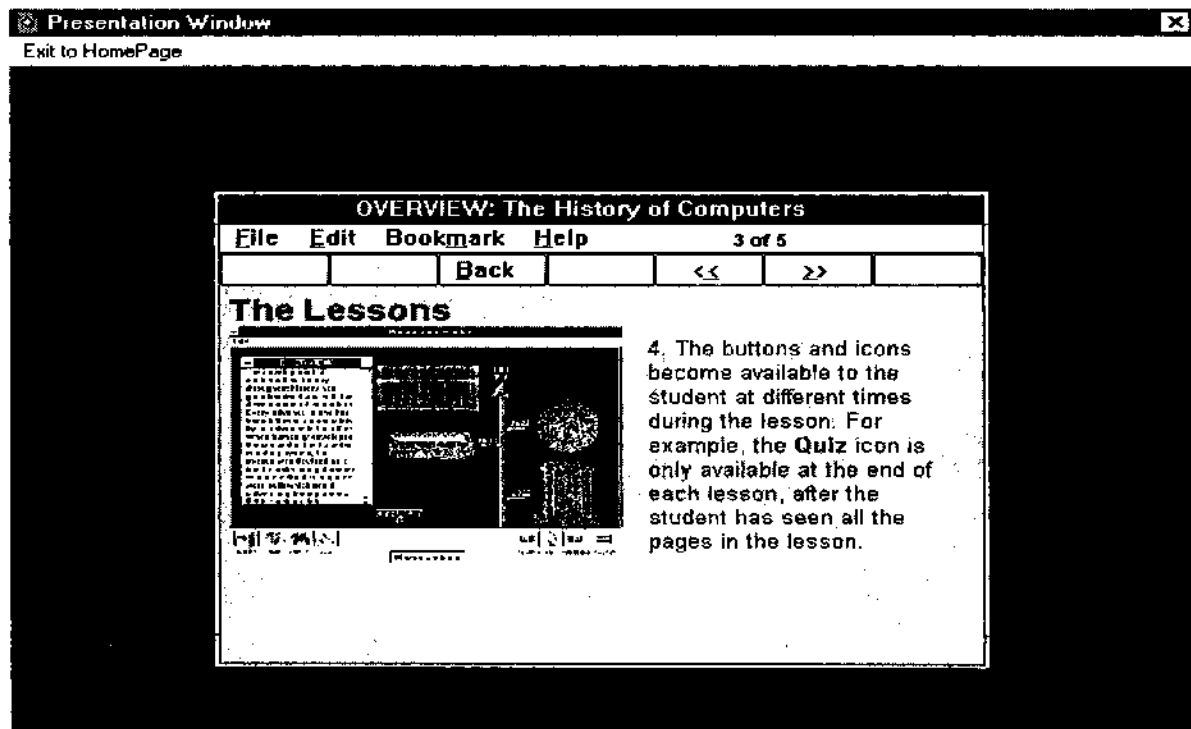


Figure 43. Overview: The Lessons Screen 4 of 5

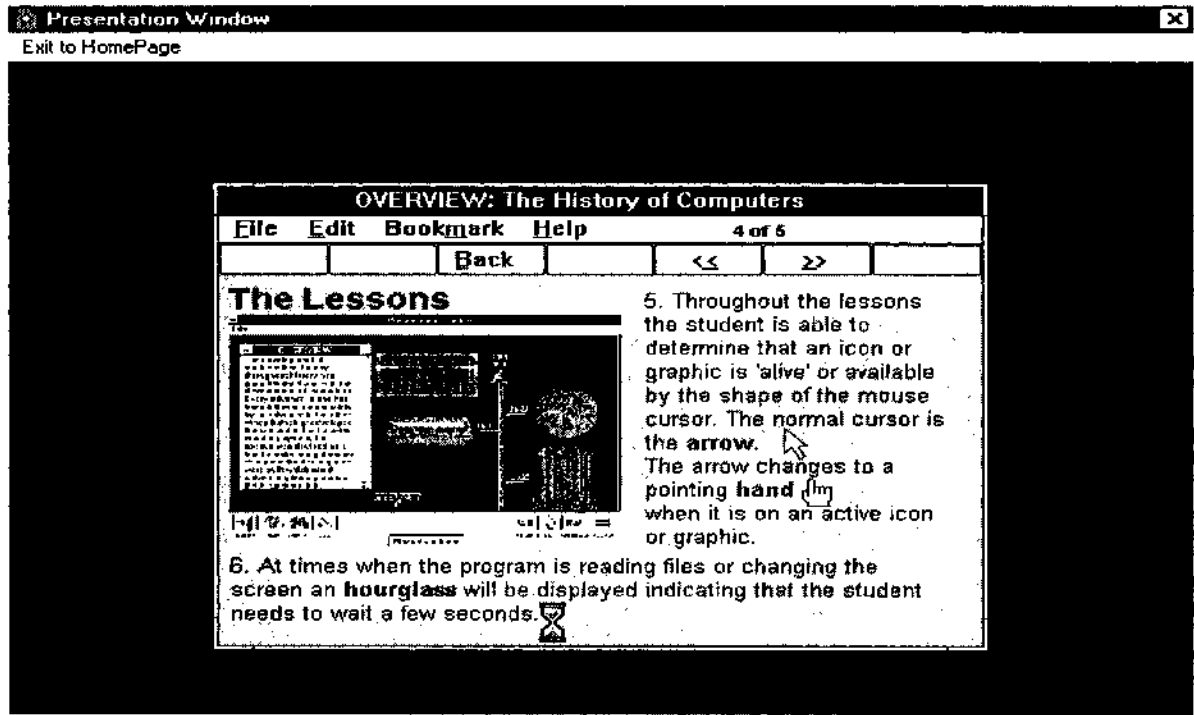


Figure 44. Overview: The Lessons Screen 5 of 5

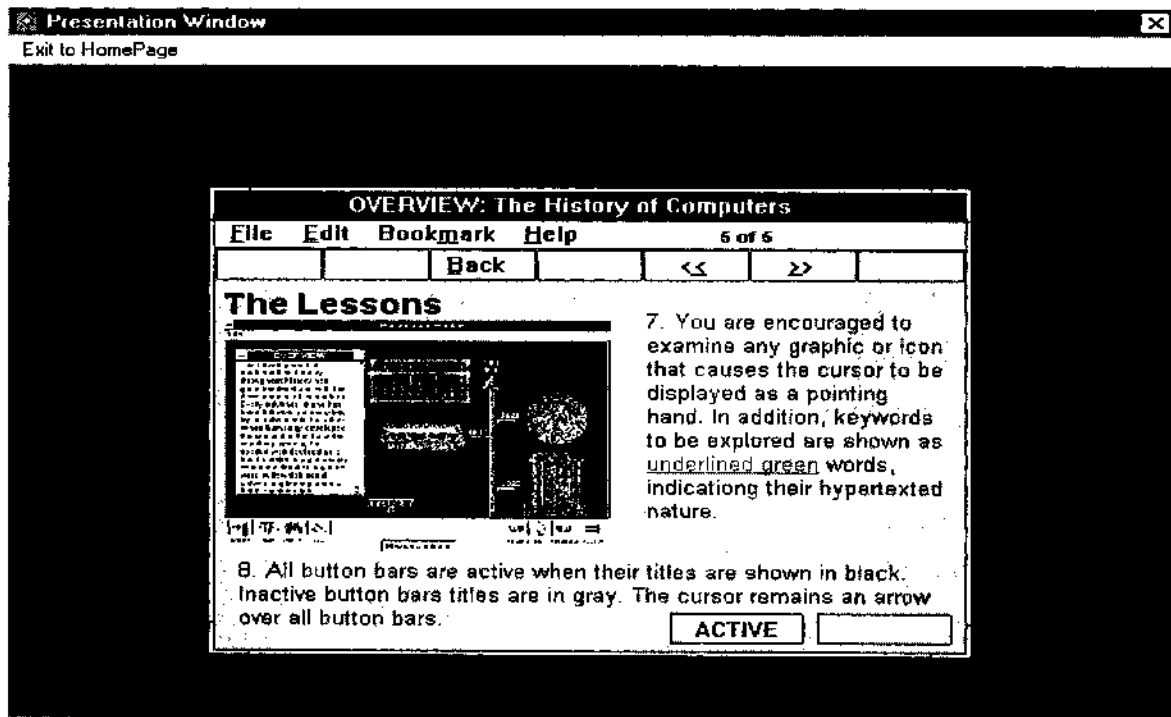


Figure 45. Overview: The Lesson Quiz Screen 0 of 5

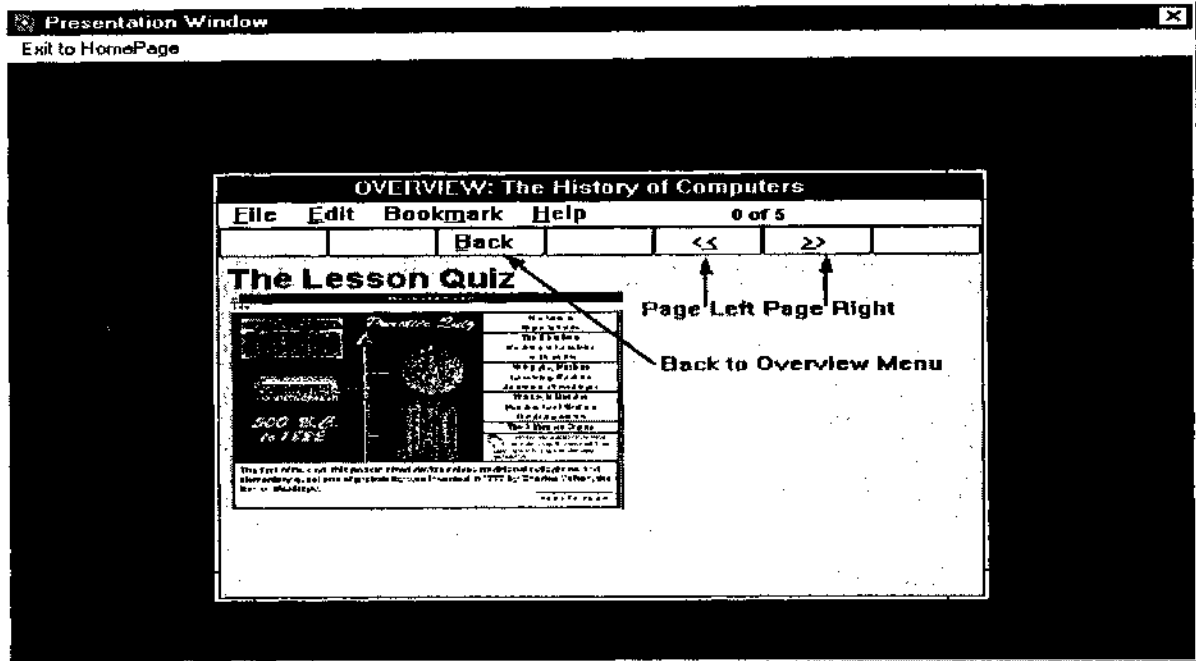


Figure 46. Overview: The Lesson Quiz Screen 1 of 5

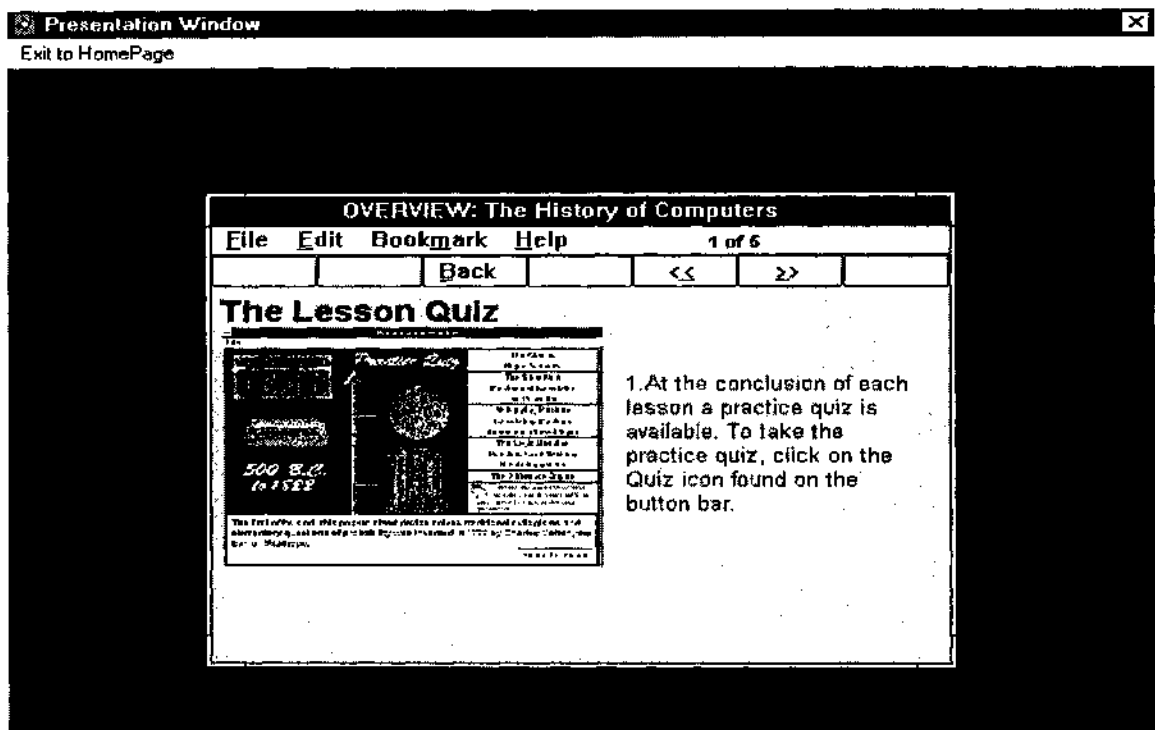


Figure 47. Overview: The Lesson Quiz Screen 2 of 5

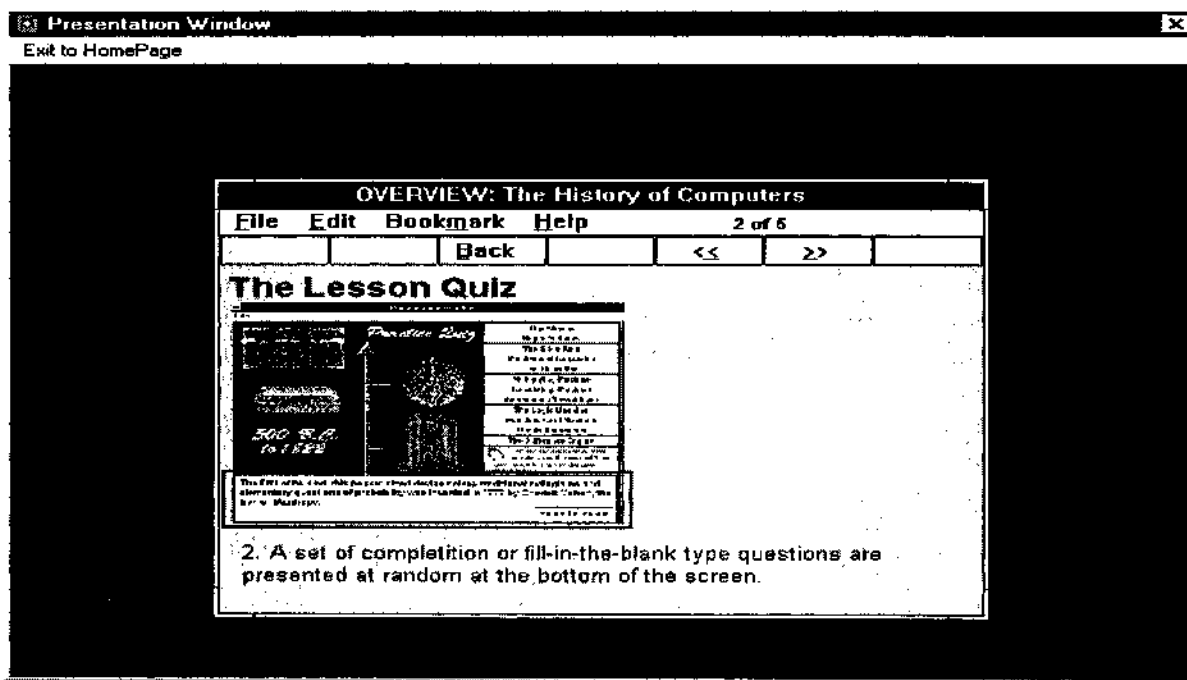


Figure 48. Overview: The Lesson Quiz Screen 3 of 5

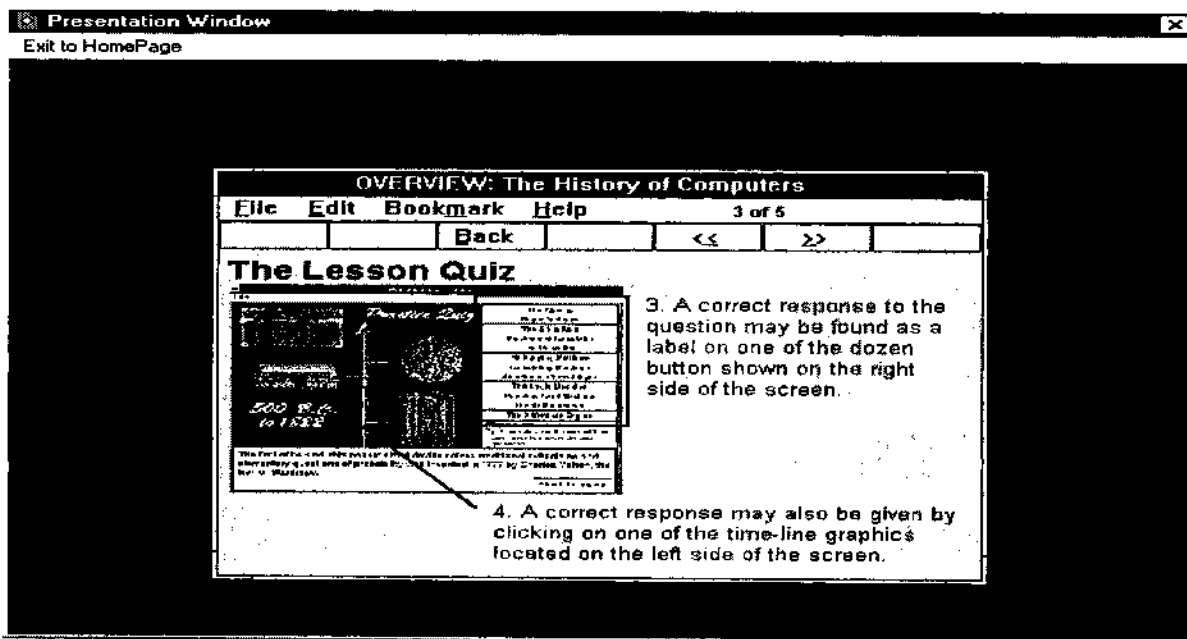


Figure 49. Overview: The Lesson Quiz Screen 4 of 5

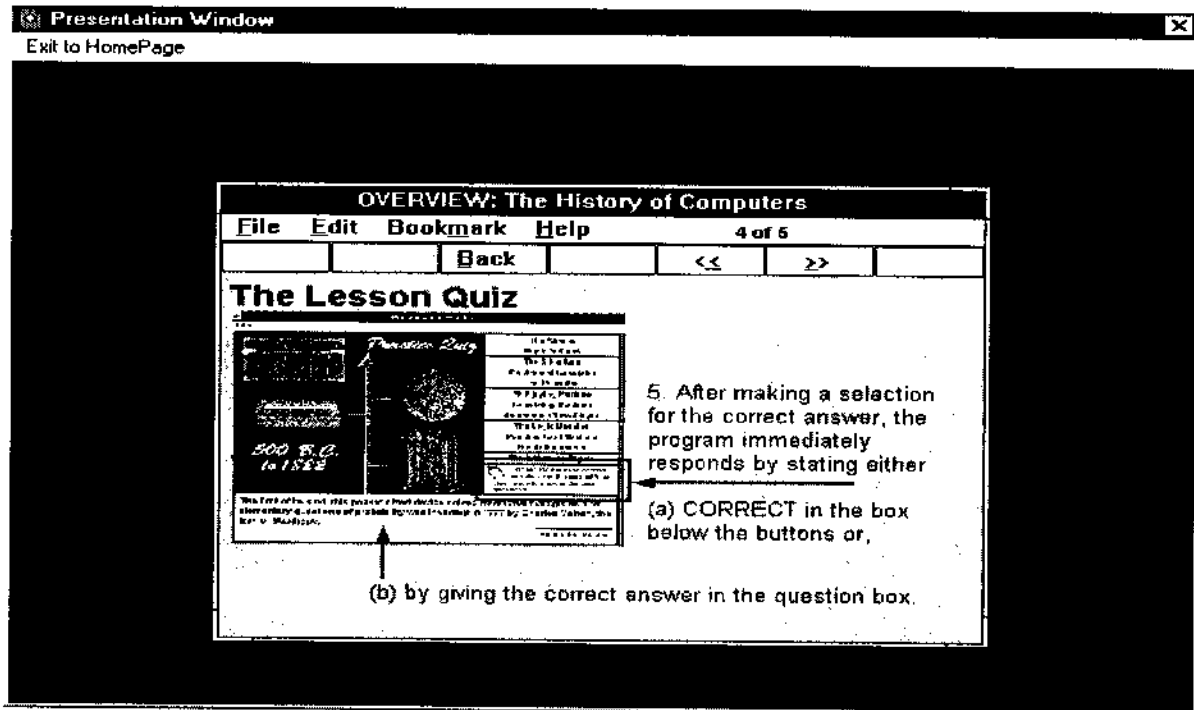


Figure 50. Overview: The Lesson Quiz Screen 5 of 5

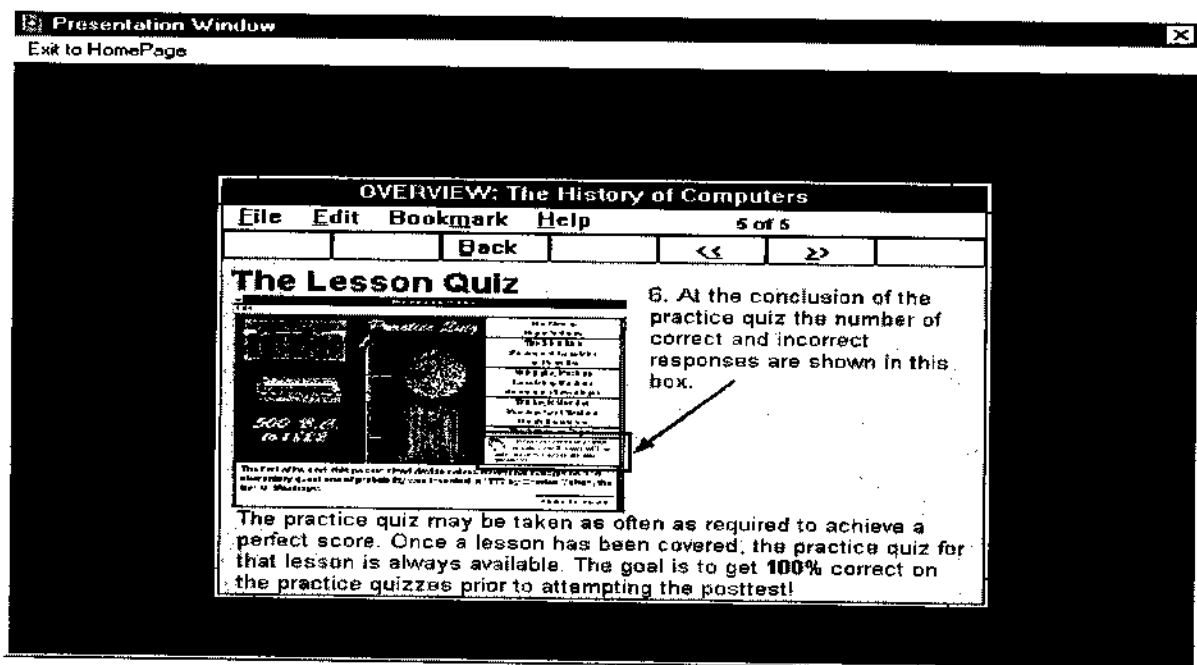


Figure 51. Overview: The Navigation Icons & Buttons Screen 0 of 11

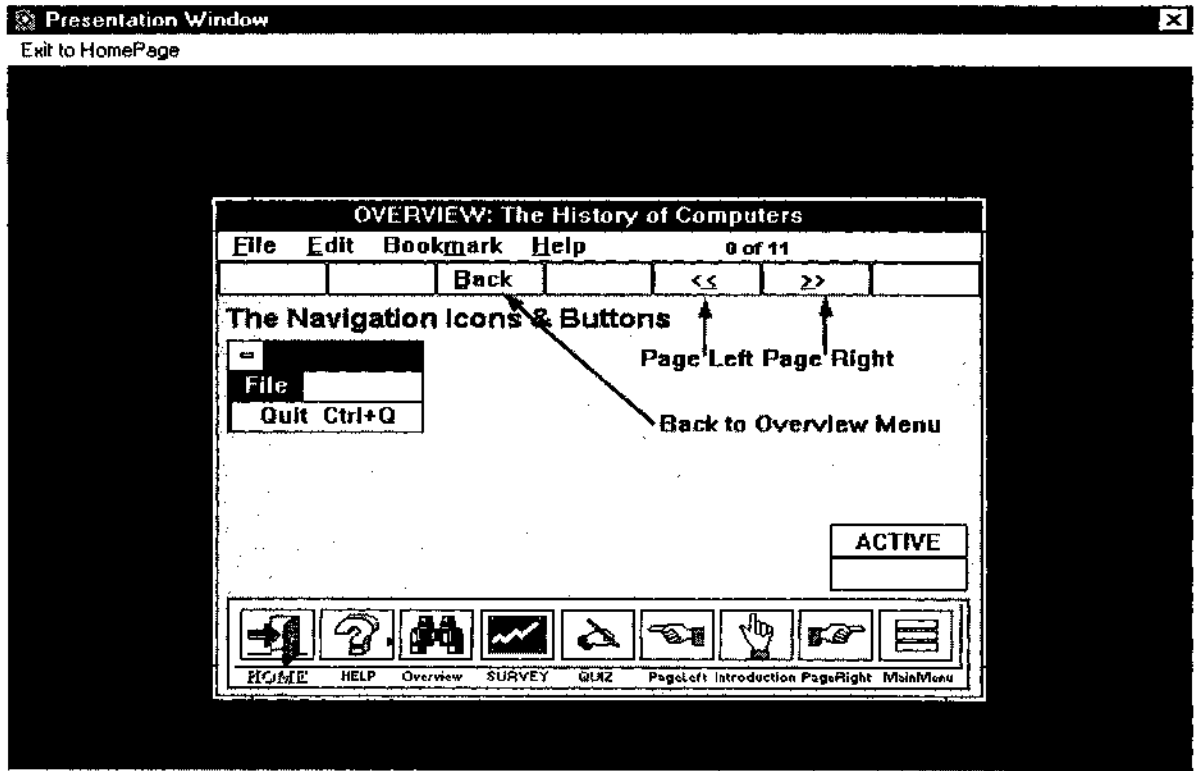


Figure 52. Overview: The Navigation Icons & Buttons Screen 1 of 11

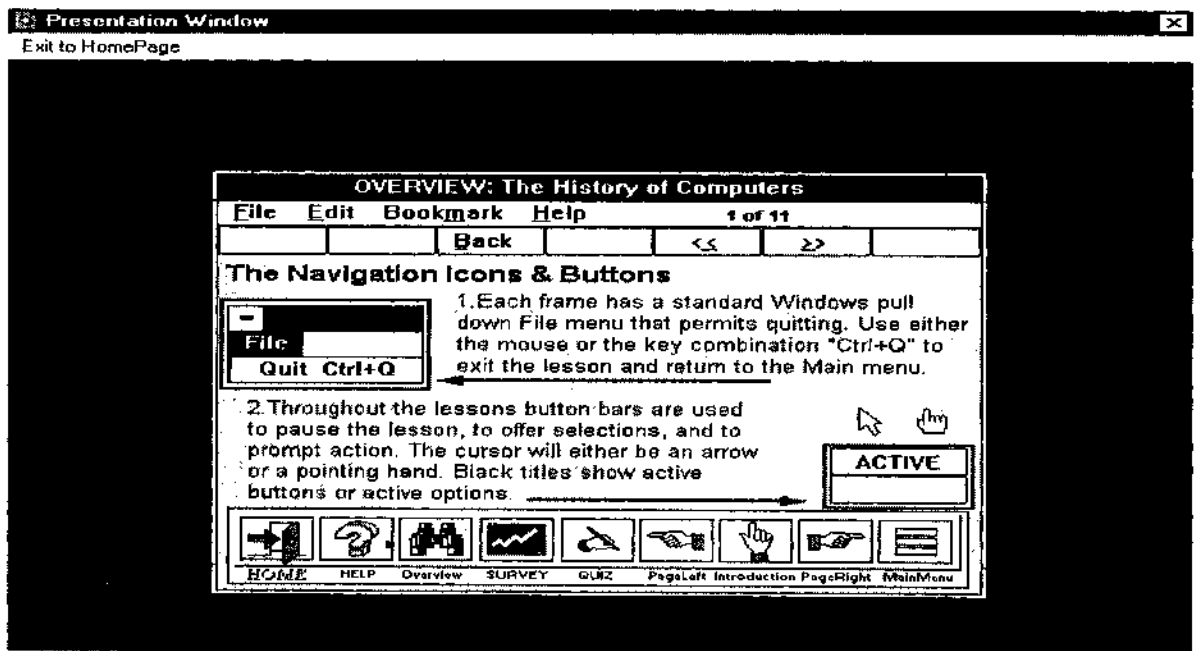


Figure 53. Overview: The Navigation Icons & Buttons Screen 2 of 11

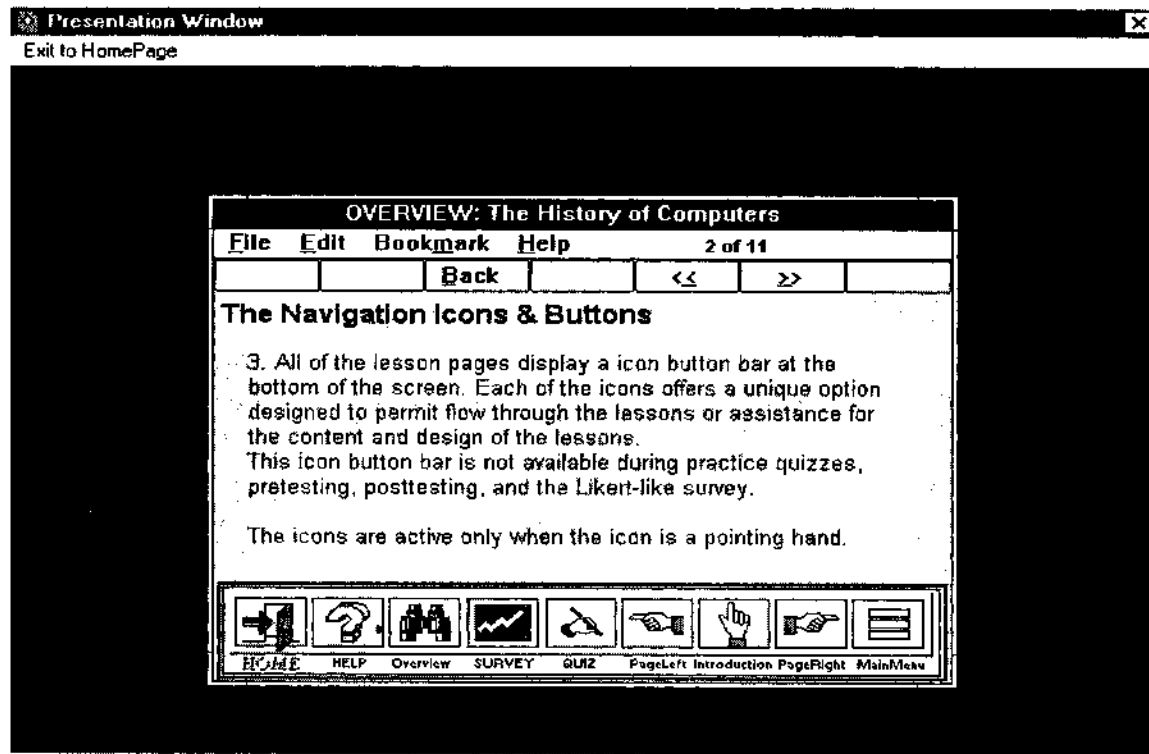


Figure 54. Overview: The Navigation Icons & Buttons Screen 3 of 11

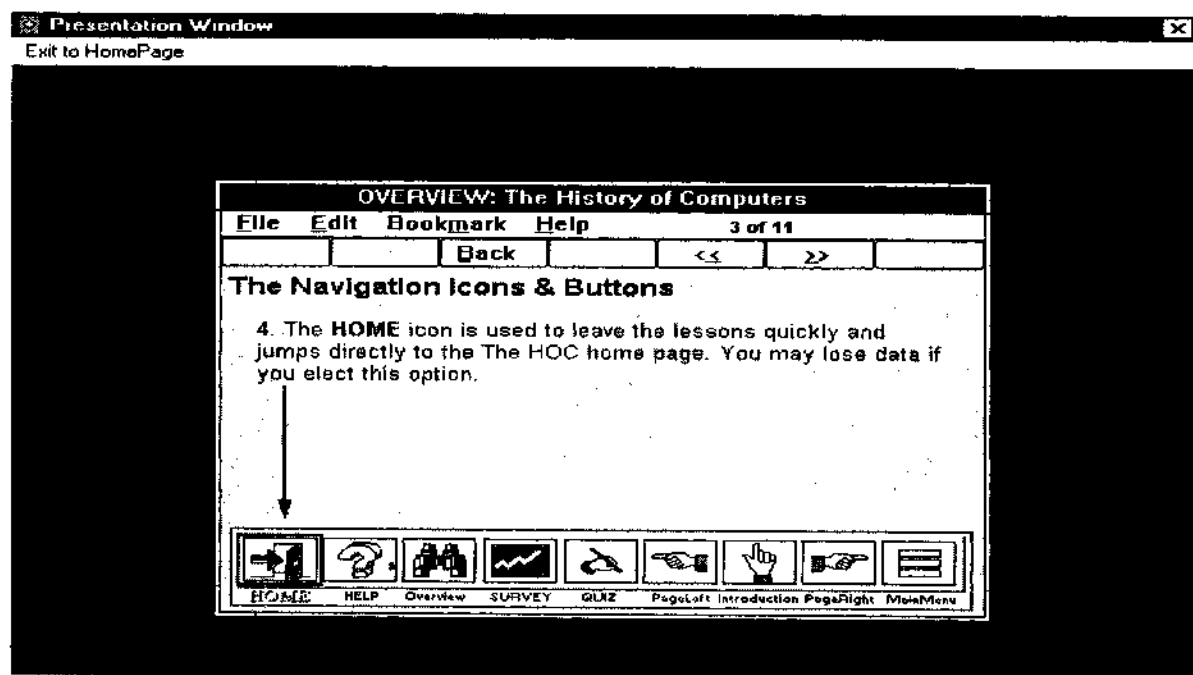


Figure 55. Overview: The Navigation Icons & Buttons Screen 4 of 11

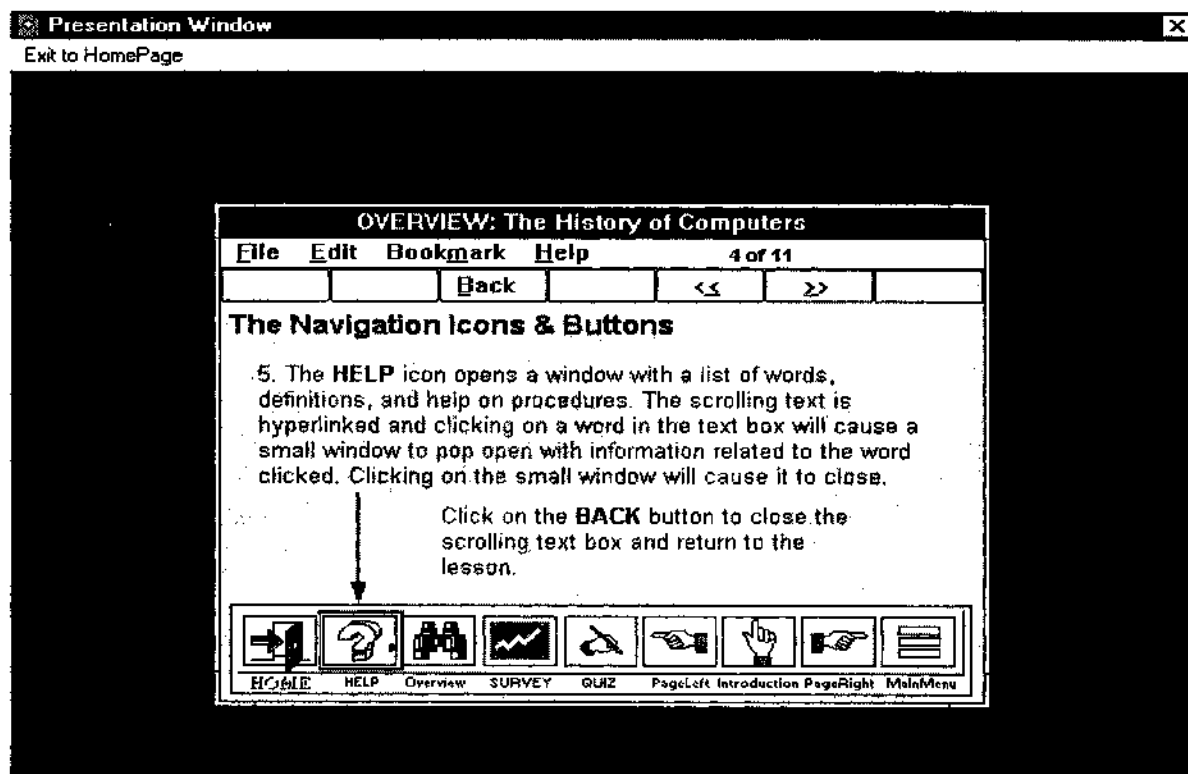


Figure 56. Overview: The Navigation Icons & Buttons Screen 5 of 11

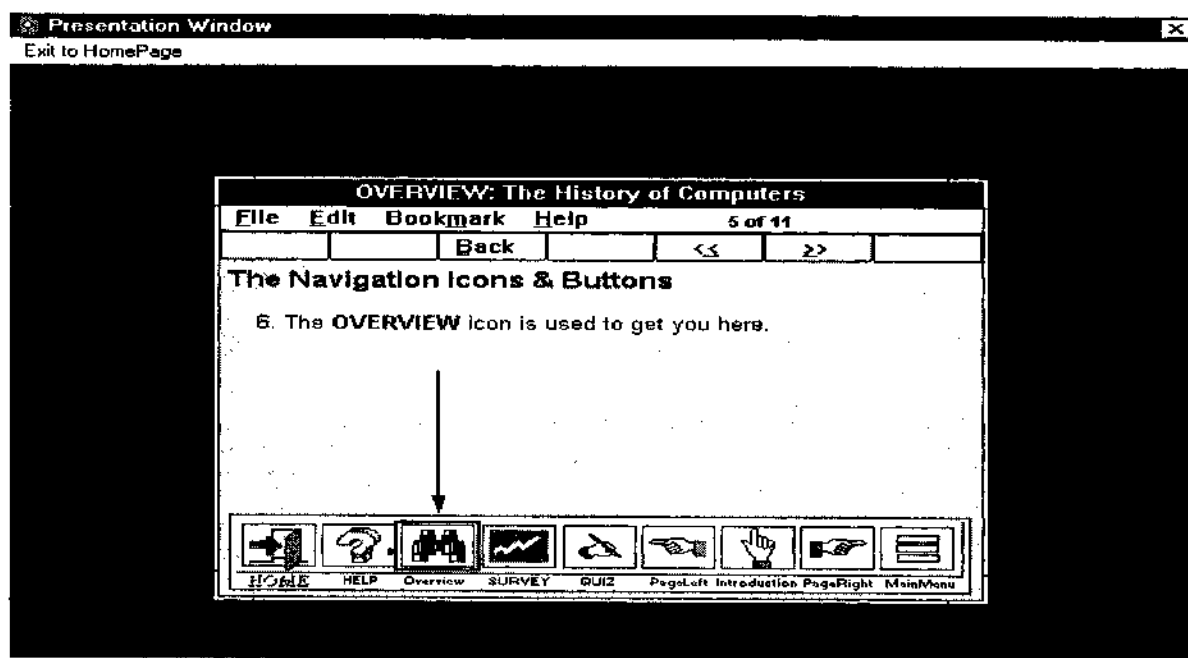


Figure 57. Overview: The Navigation Icons & Buttons Screen 6 of 11

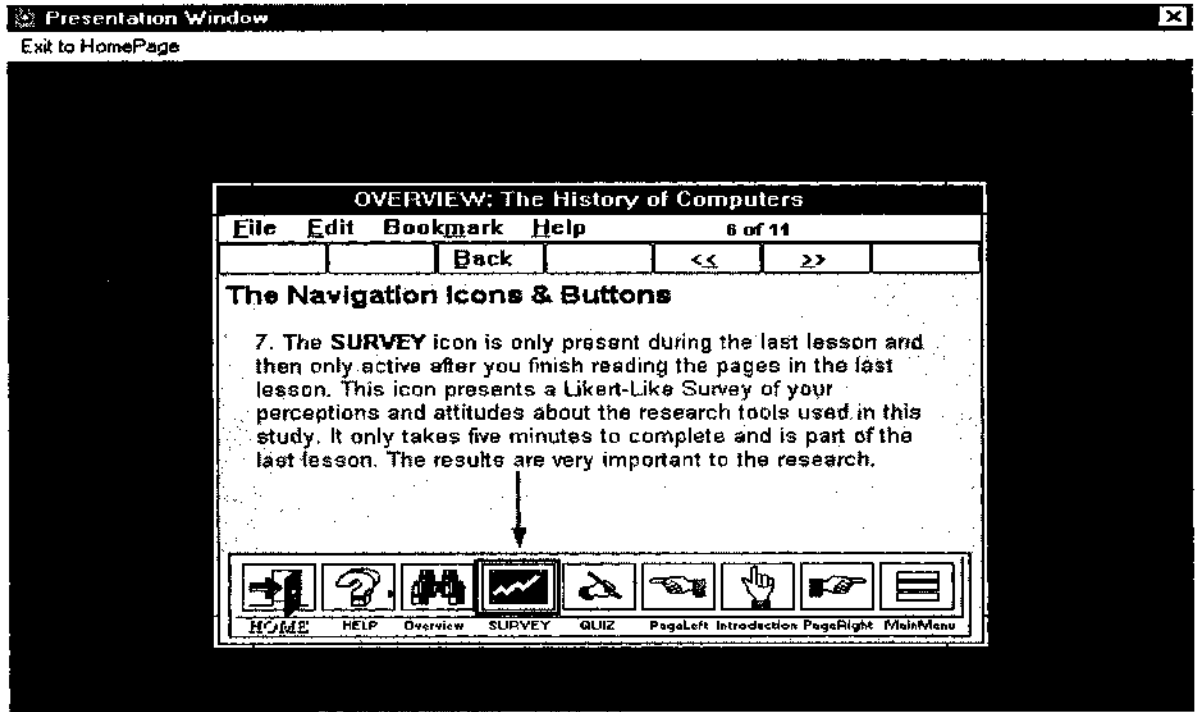


Figure 58. Overview: The Navigation Icons & Buttons Screen 7 of 11

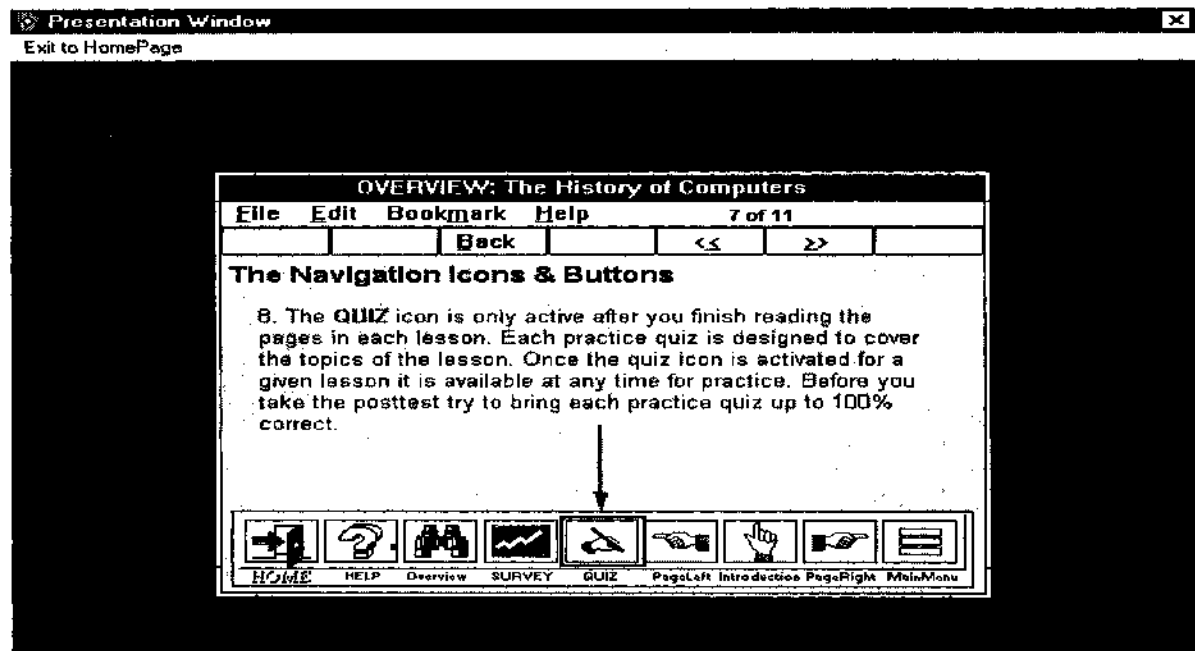


Figure 59. Overview: The Navigation Icons & Buttons Screen 8 of 11

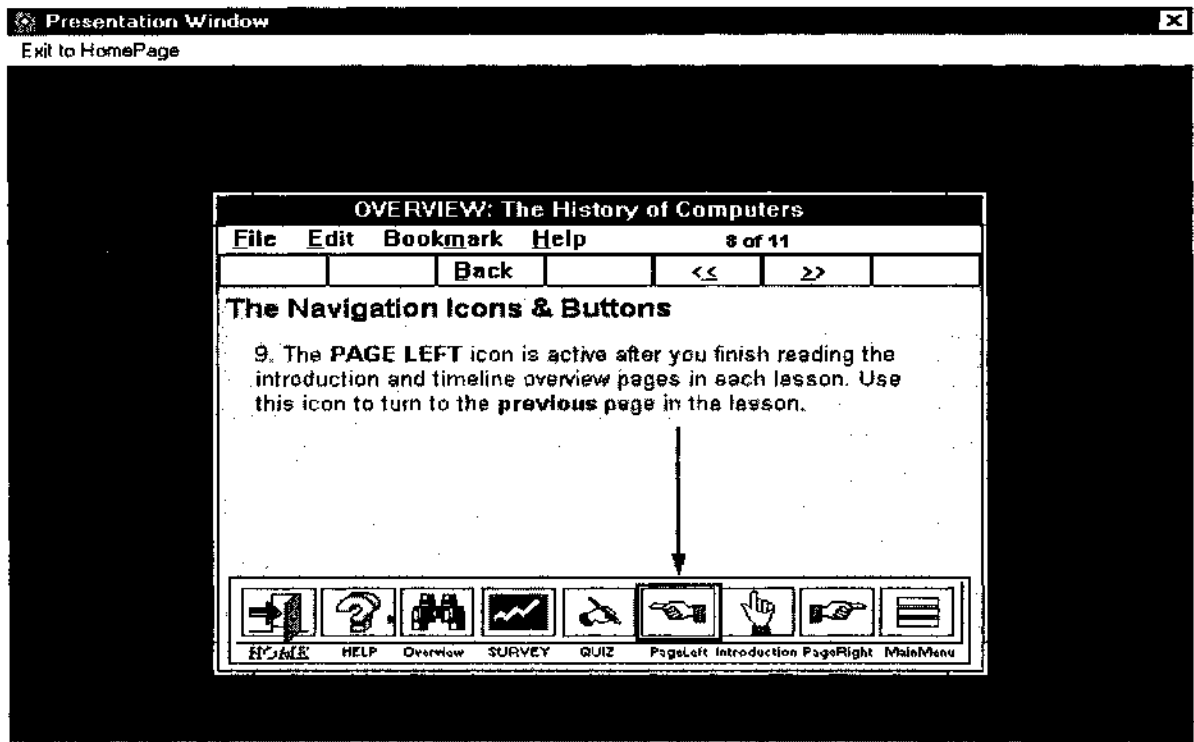


Figure 60. Overview: The Navigation Icons & Buttons Screen 9 of 11

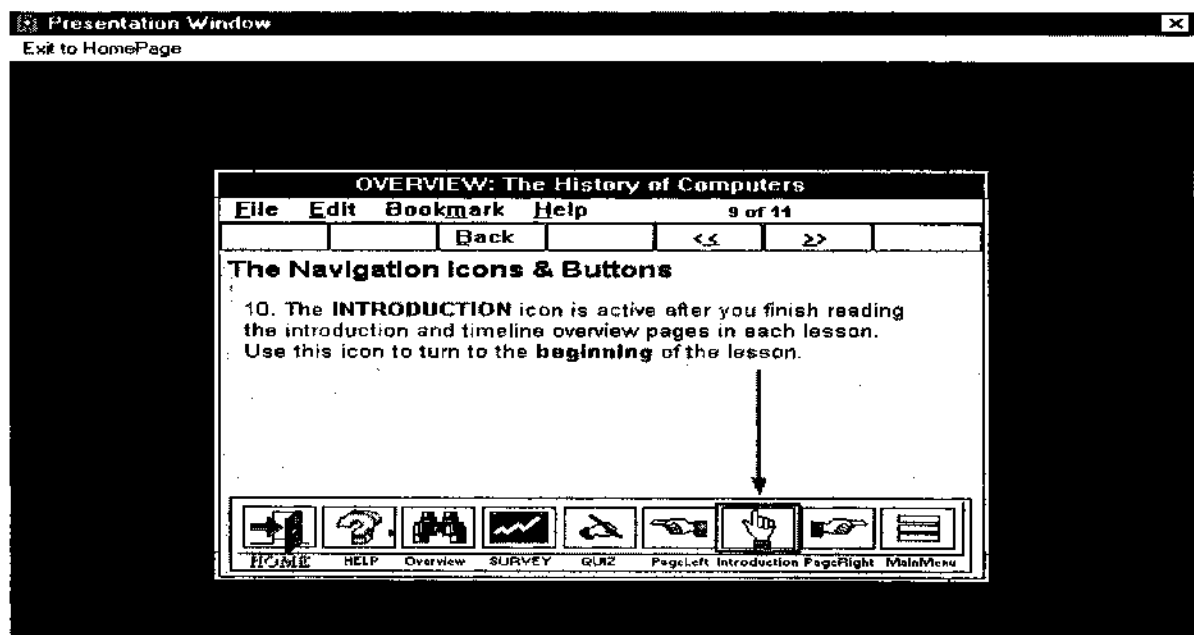


Figure 61. Overview: The Navigation Icons & Buttons Screen 10 of 11

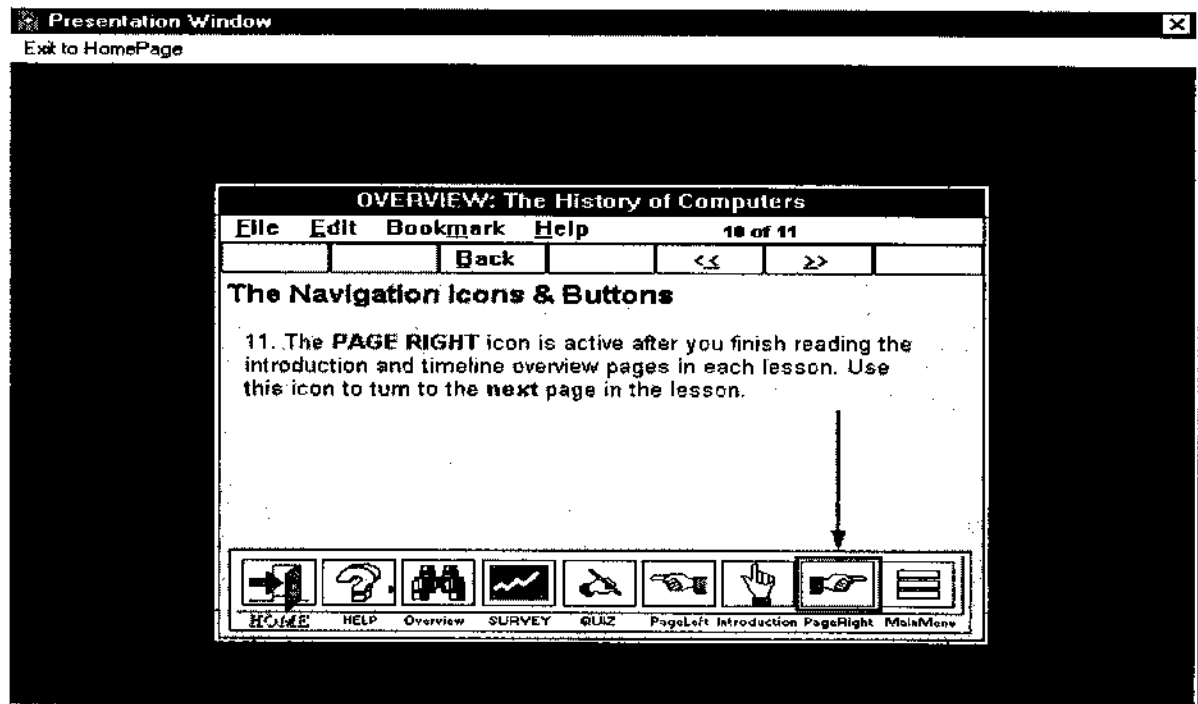


Figure 62. Overview: The Navigation Icons & Buttons Screen 11 of 11

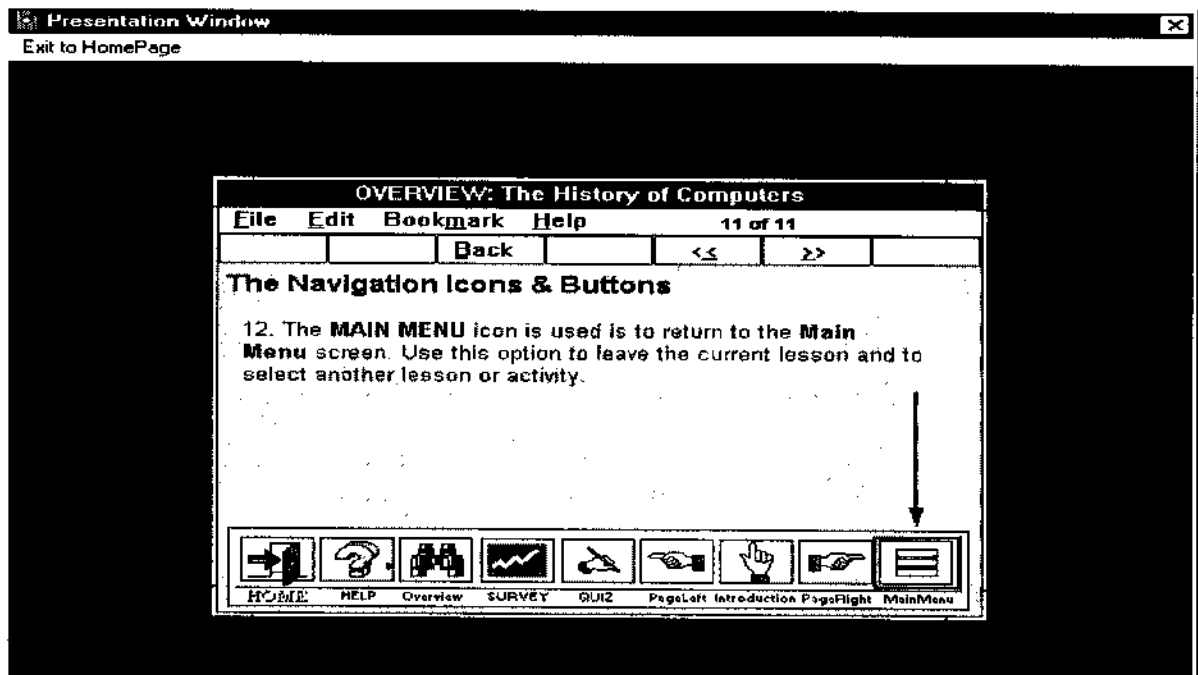


Figure 63. Overview: The Likert-Like Survey 0 of 4

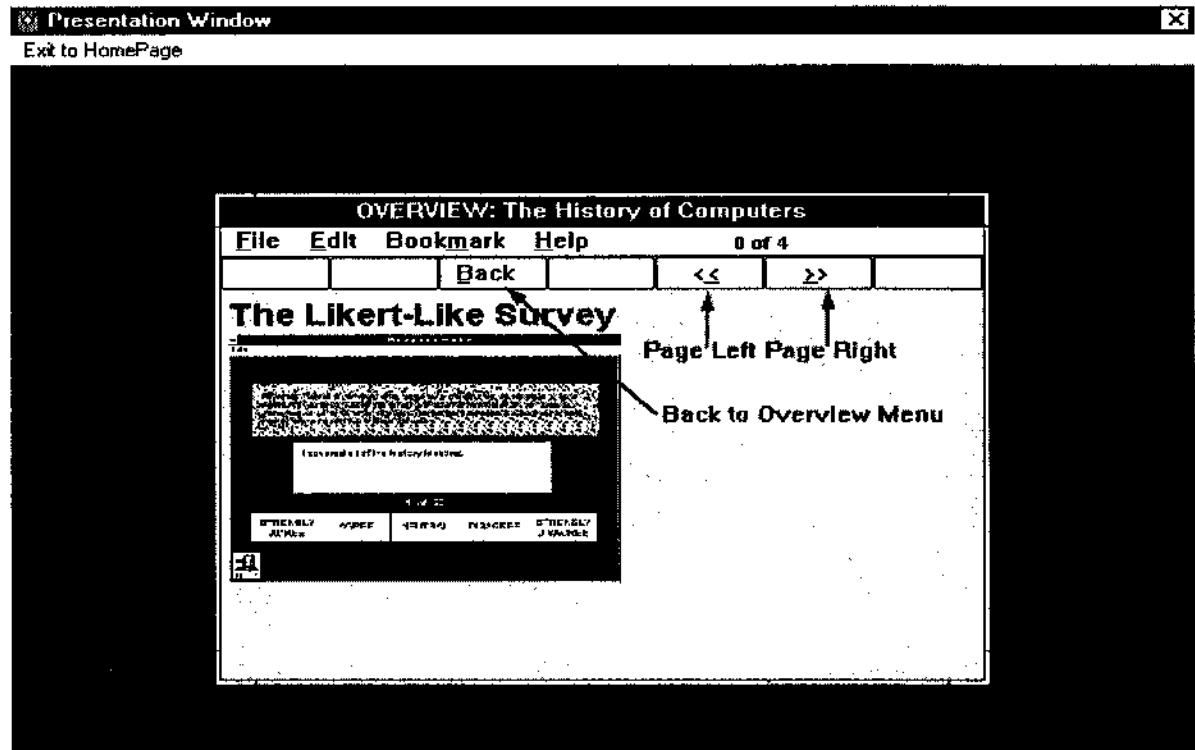


Figure 64. Overview: The Likert-Like Survey 1 of 4

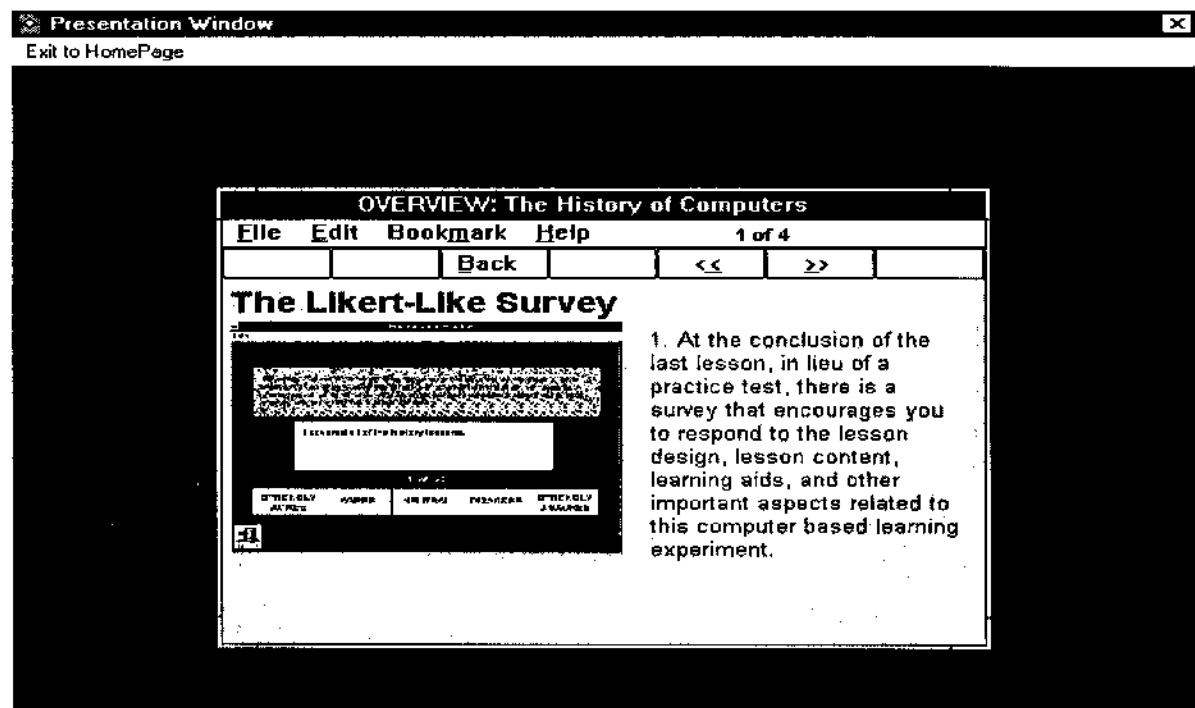


Figure 65. Overview: The Likert-Like Survey 2 of 4

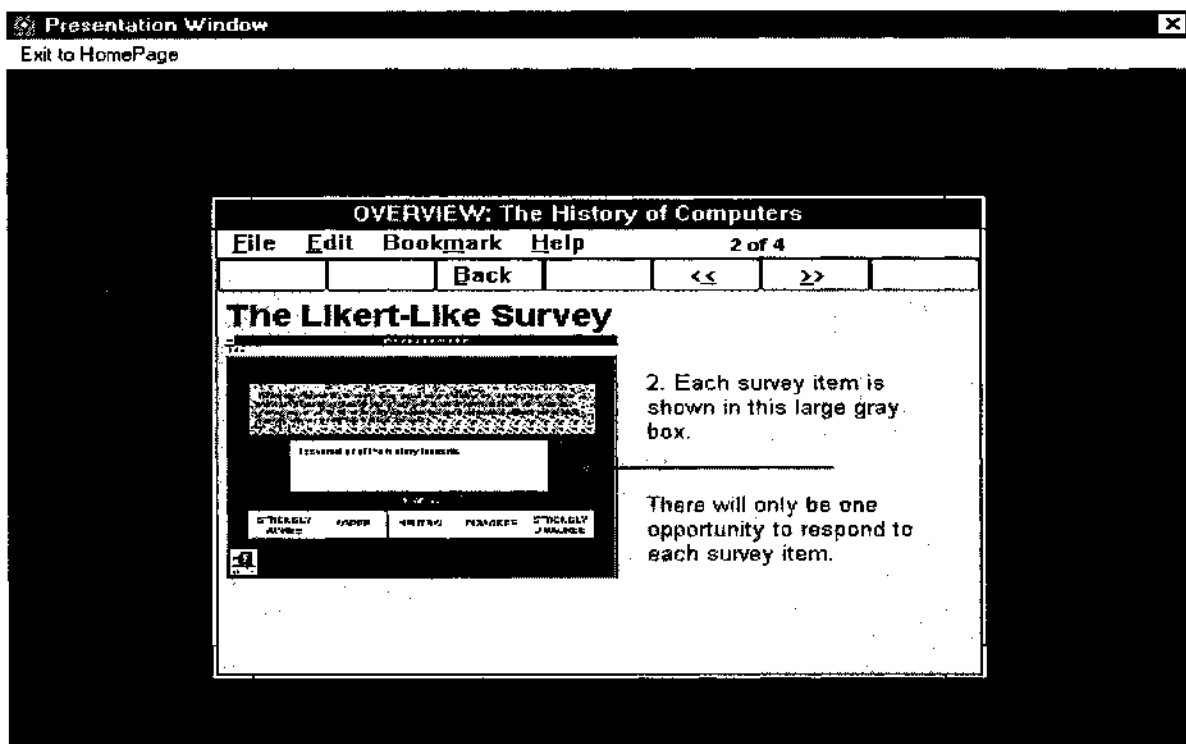


Figure 66. Overview: The Likert-Like Survey 3 of 4

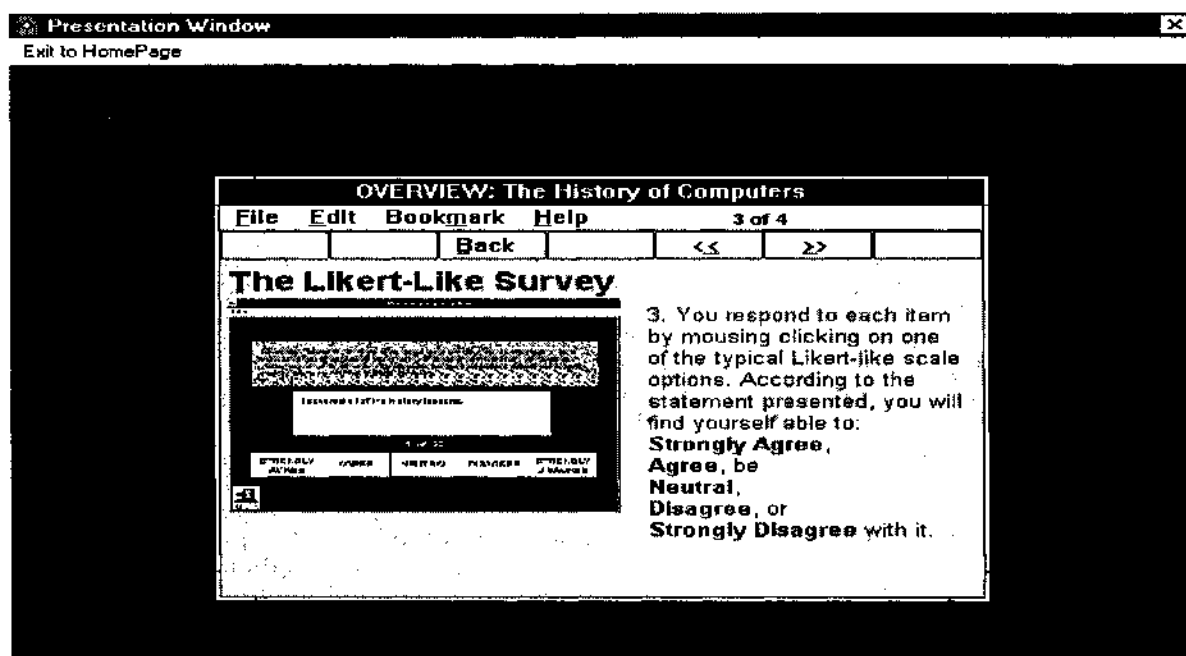


Figure 67. Overview: The Likert-Like Survey 4 of 4

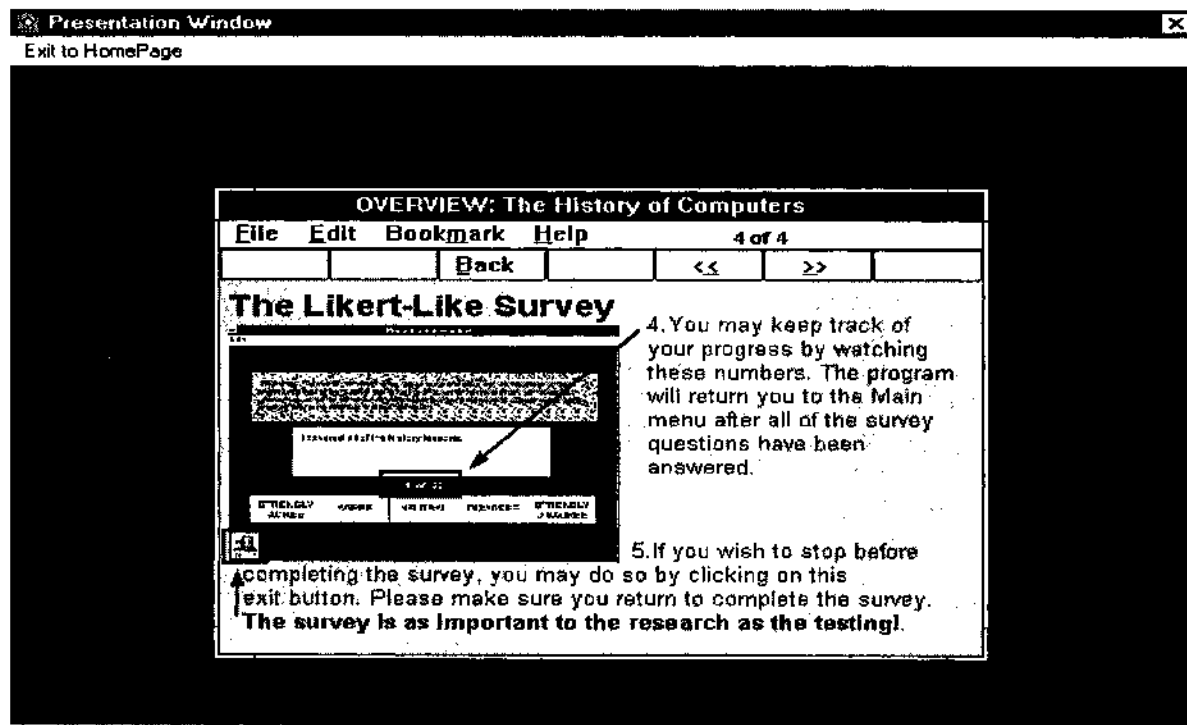


Figure 68. Overview: About the Research Screen 0 of 1

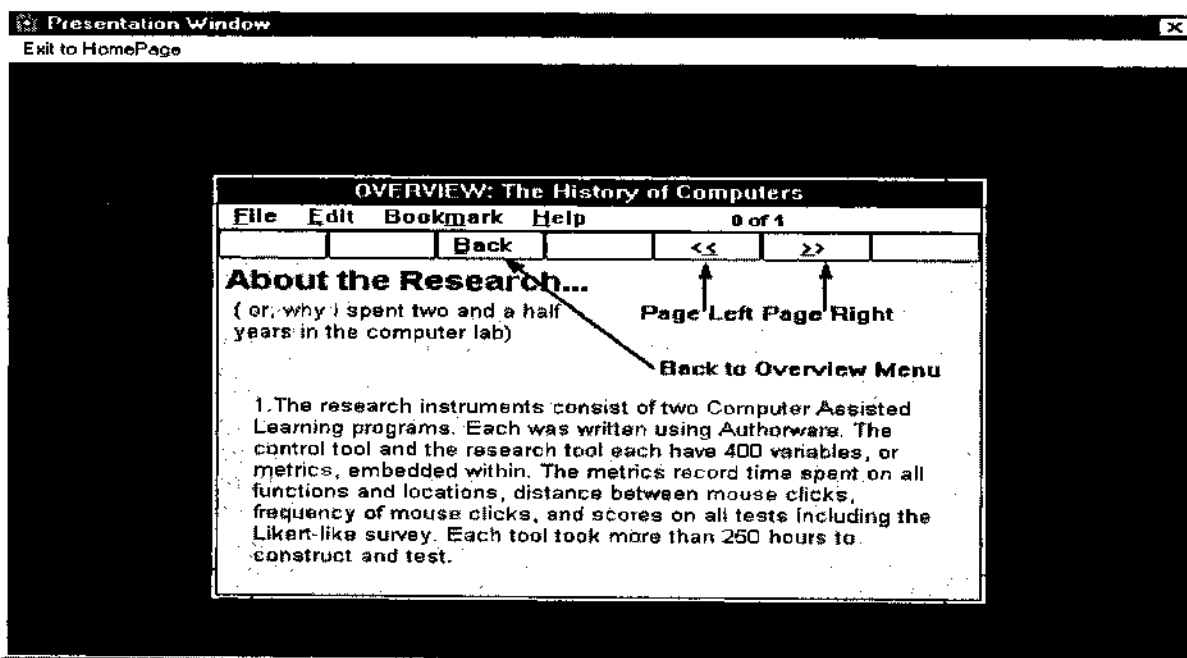
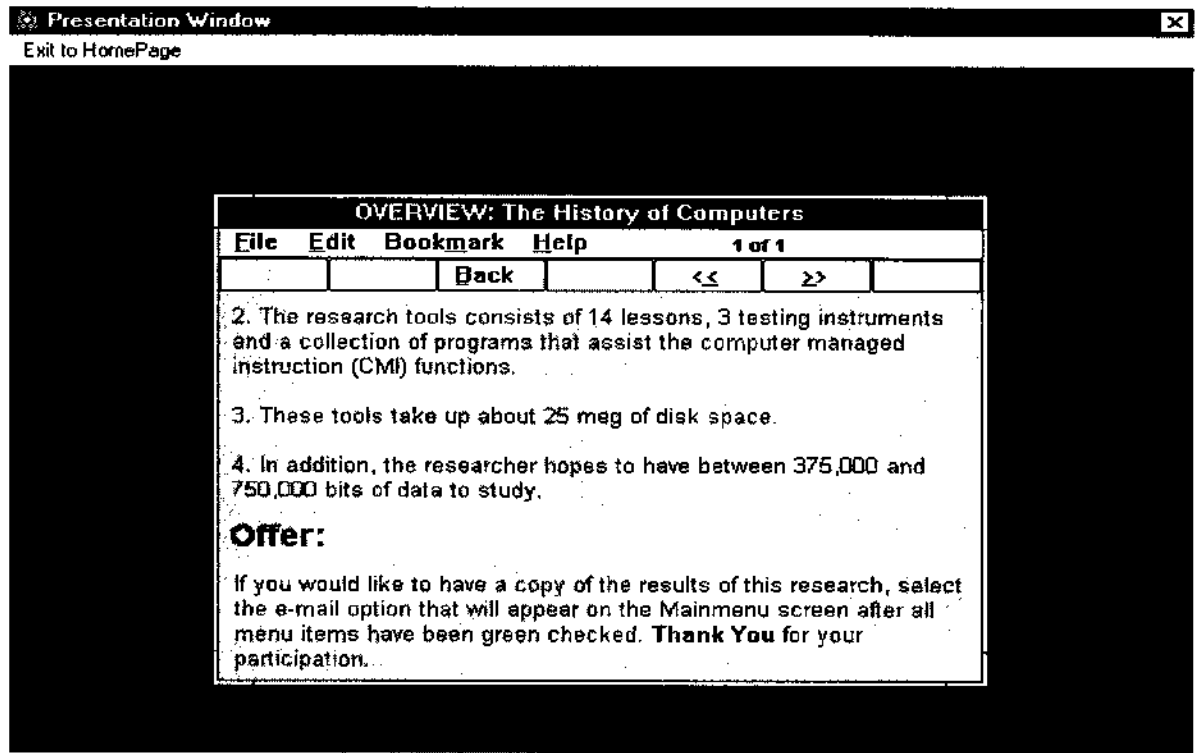


Figure 69. Overview: About the Research Screen 1 of 1



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