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The design of a dynamic book for information search

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Information-seeking skills are central to many learning tasks, from finding simple facts and comparing events in an encyclopedia, to pursuing complex research questions. Electronic document/database systems are touted as alternatives to piles of paper for accessing information, yet our current understanding of how people search for information provides few clues about how to improve the design of such systems. Dynamic books are a powerful electronic transformation of information that could potentially offer multiple paths through complex information and help us actively in searching. Within this context, this paper explores how people look for information and how the design of dynamic books interacts with the search process. It also describes a simple dynamic book, based on a world history textbook, implemented in the Smalltalk programming system, and used by students to answer questions.

1. Introduction

Samuel Johnson's adage is an appropriate starting point: "Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it". The ability to seek information is an important component in the larger process of learning and inquiry. Education, however, should impart more than the ability to point to some facts in a book. Of more importance are knowing how to pose the right questions and how to use information effectively once it has been found. Is the information important and how does it relate to what else we know? Assuming that we can describe what we want and can manipulate and integrate the information that matches our successful description, we are confronted with the problem of how to find relevant information.

The rate at which our information world is growing compounds the task of searching. In addition, paper constrains the presentation of complex information to a linear style. Electronic information systems (e.g. "teletext") have been regarded as panaceas, but actual systems often do not venture beyond the imitation of traditional media, functioning merely as automated page turners. They should, however, offer the potential of increased availability of information, shared access to up-to-date versions, alternate presentation of information, flexible access through content and multiple indexes, and active help in searching. Help in searching includes not only augmenting and suggesting search methods, but also managing the new information created about the search itself: where have we looked and what should we look at next. These more powerful electronic versions of books can be called "dynamic books."

Electronic information systems are inevitable in many areas, including education, and will be increasingly fast to access and less expensive to own. The real question for us is how these systems should be designed and evaluated, and not whether they will replace paper books for a variety of tasks. How well do they help people find

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what they need by providing a set of search operations and a structuring of the information environment?

Access to information touches many areas, each with its own focus: indexing and representing articles in library science, presenting and learning structured information in education and psychology, authoring and distributing books in publishing, and representing and retrieving information in computer science. A related dissertation (Weyer, 1982) surveys and explores these areas. This paper will take a brief look at the search process from both the human and computer points of view. It will explore human strategies for locating information in a database and how these strategies interact with the design of a user interface.

2. Search

Selecting and arriving at a destination on a journey can serve as an analogy for asking and answering a question (or posing and solving a problem); planning the trip and navigating a course are similar to describing and locating areas in the information terrain. The original destination may be too vague and in need of further specification, or if it is very distant, the traveler may choose to break the trip into a series of smaller, connected trips. Knowing about maps (which vary in detail, accuracy and purpose), weather *en route*, and the available modes of transportation can aid in planning a successful and economical trip. Landmarks along the way indicate the direction and serve as benchmarks of progress. During the trip, the traveler may decide to change destinations or vehicles, explore or enjoy the surrounding terrain, travel in circles over old territory, reach impasses and backtrack, or finally arrive at some destination.

To aid in search (as do maps for navigation), information has often been structured, and indexes provided, so as to reflect some underlying natural order or set of relationships among concepts, or to anticipate the most commonly asked questions. A book may be written in a linear, page-oriented order that may be alphabetical, chronological, geographical or pedagogical in its organization. Pieces of information are related to each other by their physical proximity in a paragraph, on a page or on neighboring pages. A subject index provides access to parts of the book in some other order. A good teacher, a set of questions or the authors can help provide connections and cross references to seemingly distinct sections and ideas; footnotes (and parenthetical remarks) refer to details of minor interest, named references to figures and chapters lead to other pages, and bibliographic citations point to other books or articles.

What happens, however, when your vocabulary, organization or perception of a subject domain does not match the ones provided? In deciding to read footnotes as soon as they are referenced, you may suffer minor inconvenience by losing your place in the main narrative. You may have more difficulty in trying to find a word in a dictionary if you have misspelled it, know only a synonym for it or know only how it sounds. How do you locate work "related" to your own: by reading through everything about man–machine interfaces (for example), asking a colleague or attempting to specify a set of keywords or commonly used free-text terms for retrieval from some information system?

As an example of how flexible a search strategy must be, assume that we use a history textbook or encyclopedia to satisfy the following task: "Name five heads of state who died before the age of 40". If our subject index does not contain a list of

important government figures under "Heads of State", or a convenient heading such as "Death: young leaders", we may have some trouble with this question. Perhaps we can think of an important head of state, find his name in the index and read to find out whether dates of birth and death put him in the desired category. If he died young, we might look for descriptions that could apply to other leaders. Alternatively, we can start under "King" in the subject index (if that's a subject term), then try "Queen" and "Emperor", and perhaps leave "Presidents of the United States" out of our search if we know they are rarely that young when elected. As a last resort, we can read through the entire text or go through the subject index and examine every person's name and refer to the text to see if he or she was a head of state who died young.

If we knew that England had a particularly bloody history, we might start looking there. If the author considered this information important, there might be tables of important leaders, vital statistics, and their significant accomplishments in prominent places in each chapter or unit. Timelines in each chapter could summarize important events including births and deaths of monarchs, and the time could be computed between these dates. Taking a different tack, we might look for appropriate causes of death for heads of state that could result in an early demise, such as "Assassination," "Revolution" or "Stress". Perhaps we have some situations in mind in which leaders are in jeopardy: for example, young leaders whose countries are ruled by their guardians may have fatal "accidents" (and their parents may meet untimely ends as well); leaders of weak central governments surrounded by strong independent barons may be overthrown and killed.

Tactics for seeking information are part of an overall strategy or plan. Bates (1979) provided a good review of articles about the "reference process" and discussed "search tactics", and in a related article (Bates, 1980) listed "idea tactics" for generating new approaches to a search. In addition to interacting with a person's background and training and the task at hand, tactics are constrained by the query language and user interface provided. Reisner (1981) surveyed query languages that interact with an underlying data representation, primarily the relational model. Some examples of user interfaces are the menu-driven, hierarchical framework of ZOG (Robertson, McCracken & Newell, 1981), supplying sample values in a two-dimensional form in Zloof & de Jong's (1977) SBA system (based on Query-by-Example), and the progressive refinement of examples to construct abstract descriptions (Williams, 1981; Tou, 1982).

Ultimately, a comprehensive model of the search process is desirable. It should represent the background of the searcher, the kind of training received in using tactics and interfaces, the questions or tasks posed and the structure and content of information sources used. It should explain or predict something about the sequence of a user's actions: at a given point in the search, what happened and why, and what other actions could have been chosen? A larger model of learning could then ask how recall or transfer of requested or incidental information is affected by these search factors or related factors. The particular experiment summarized here focused on a small area: observing existing search behavior and varying the interface for structural material to see the effect on choice of search tactics and overall search strategy. Other important educational questions not directly addressed are what would happen with students of different ages or experience, how much additional training and practice

is necessary to become an "expert", what did students learn or remember from answering a series of history questions, and how useful would a dynamic book be for other purposes?

3. Dynamic books

By extracting and extrapolating from many existing and imagined information systems, we can come up with a description of a dynamic book that shows its advantages over traditional media and distinguishes it from simple representations on a computer. Several actual systems that exhibit aspects of dynamic behavior are the NLS system of Englebart & English (1968), Negroponte's (1979) Dataland, systems for full-text search such as Mead Data Central's LEXIS, Carbonell's (1970) SCHOLAR system (that inferred answers from a semantic network of geographical knowledge) and an on-line aircraft manual evaluated by Rouse & Rouse (1980). Hypothetical systems have provided visions of dynamic books also: Bush's (1945) "Memex", a desk-sized information tool, and Nelson's (1981) 'Xanadu hypertext" system for dynamic document content and linkages with other documents.

A dynamic book is a new way of interacting with information. Ideally, it should be portable, with all the ease of use we associate with paper books. A dynamic book can react to its readers, not only by changing the medium of the information from text to animated pictures or sound, but also by transforming the organization of its content into a more useful form and by actively aiding the reader in the search process. A dynamic book is a particular view on an interconnected network of knowledge: it may correspond to an actual entity written and published by an author, or it may be a virtual book built by looking at other books and materials from specific points of view.

Paper books are, by their physical nature, static stores of information. The information content may change, but corrections and new editions are infrequently published. Electronic books can be more responsive to such change, but still tend to mimic the mostly linear representation of information imposed by the paper medium. The primary organization of the book, the linear order of sentences, paragraphs, and pages, is also fixed at the time it is published. Secondary organizations, such as footnotes, a subject index or bibliographic references, transcend the physical order of information by making new connections, but they are more cumbersome to use than the primary organization: it is easier to read the next paragraph on a page than to access and read a different page or a different book.

Not all perspectives of a book are of equal merit. An essay on philosophy might be read from beginning to end, which is the author's perspective; it could also, however, be related to the author's other works, compared with works on the same topic by other authors, or interleaved with commentaries by critics and annotations by the student, examples of three alternative perspectives. A dynamic book could offer several curricular views of a subject, each suited to a particular learning style or audience. For example, similar information content could appear in the form of a game, experiment or cartoon, and be used for an introduction, remediation, or review by individuals with different backgrounds. The first-time reader of a dynamic novel may choose to follow the author's original version but may occasionally want to review the numerous characters already introduced when names and roles become too confused. On the other hand, the repeat reader or literary student may wish to see

alternate interpretations of the work made possible by sorting *flashback sequences*, interspersing a critic's commentary or presenting sequences of events from the point of view of different characters.

When reading a paper book, if you follow the text to a footnote and then go to the appendix, or start with the subject index and try to keep track of the many places in the text to which you want to refer, you can rapidly run out of bookmarks, fingers and short-term memory. Leaving annotations in the book margins, highlighting with a yellow marker, bending page corners or using different colored bookmarks are ways to manage this information and add some structure to a book. In a dynamic book, too, this structure could be added. More significantly, this structure could become part of the accessible information. The reader's very sequence of search actions becomes information that is describable. Not only should a dynamic book store a history of where the reader has already looked, but it should be capable of returning the reader to previous choice points along an exploratory path or suggesting places where he has not looked. So the patterns of search are themselves information, and should be viewable and modifiable to construct new patterns or descriptions. Adopting a role analogous to that of a research librarian, a dynamic book could alert the reader to new information that is relevant to these patterns, or sift through old information as new patterns are specified.

In summary, a dynamic book would be not only a new kind of container for information, but also a collection of methods for accessing this content through many forms or maps. It could aid the reader in searching or navigating through this collection of methods. These active qualities distinguish it from traditional and merely electronic information representations. If this were a dynamic paper (or part of a dynamic journal), you, as the reader, could adapt it to your style of reading and thinking, and discover more specifically which of the above is fact, research or fancy, and how it relates to what is to come. You could read it at increasing levels of detail, as a one-page abstract, a longer abstract or a longer article, or interact with the figures and bibliographic citations.

4. Environment

A simple dynamic book that exhibits some of these qualities will be described in later sections, along with some results from an experiment. This section presents background information on the implementation and use of the book. For the last ten years, the Learning Research Group (now named the Software Concepts Group) at the Xerox Palo Alto Research Centers (PARC) has had as its goal the development of a *Dynabook*, a personal computer the size of a notebook, and *Smalltalk*, a programming system for communicating with the Dynabook and handling its owner's many needs for manipulating dynamic information in diverse media (Kay & Goldberg, 1977). Several predecessors to a Dynabook and several different designs of Smalltalk have been completed. The Smalltalk-80† system is the most recent and best documented version of the language (Xerox Learning Research Group, 1981; Goldberg, Robson & Ingalls, 1982). *Findit* (Weyer & Kay, 1976; Weyer, 1982) is an experimental system written in Smalltalk for editing, retrieving and storing documents. It served as the basis for further exploration of databases, user interfaces and dynamic books.

† "Smalltalk-80" is a trademark of Xerox Corporation.

Rather than creating a dynamic book from scratch or accessing an existing database system with little control over the user interface or facilities for collecting data, the approach taken was to obtain a book already in digital form, in this case a high-school level world history textbook: *Our Common Heritage: a World History* (Roselle, 1981), used by permission of Ginn & Co. Taking a word-processing version of a book written for the paper medium provided an immediate way to begin exploration of the some of the capabilities of potential dynamic books, although it prevents generalization to the case of what it would be really like to access a book originally written with the dynamic medium in mind.

Three versions of the textbook, pictures excluded, were used in an experiment. For simplicity, Book A will be called the "paper" book; Book B "electronic"; and Book C "dynamic". However these labels may be misleading because Book A is not the published textbook but an off-line, loosely bound printout and it is used with an on-line question/answer interface, Book B has several features that are considered dynamic, and Book C is by no means the ultimate dynamic book.

Book A—A paper book. Book A consisted of two parts: an off-line paper printout of the textbook, used for finding information; and a simple display interface used by students in the experiment to select and view questions and to enter answers.

Book B—An electronic book. Book B provided the same computer interface as Book A for questions and answers, but gave access to an electronic, on-line book on the remainder of the screen through a more complex "window", or "information browser". Access to text, like Book A, was done by using page numbers. It did provide several dynamic features, however, in common with Book C: words that occurred in the current subject phrase were "highlighted" in the main text; and, as with Book C, the user could manage lists of subject phrases and text references by checking off, adding and saving items.

Book C—A dynamic book. Book C provided access to the on-line text through an expanded outline of chapter, section and sub-section headings (a 3-level hierarchy of titled locations in the text rather than page numbers as in Book B). In addition to subject word highlighting and the management of subject phrase and title references, Book C added dynamic features for matching patterns in the subject index (non-alphabetical search) and accessing an inverted subject index (additional subject cross references).

In summary, Books A, B and C possess the attributes listed in Table 1. These attributes may have an impact at several points during the search process: in the generation of subject terms (subject pattern matching and inverted subjects of Book C); in faster probing of the subject index for the existence of terms (fast, random subject index access); in tracking of immediate and saved items (title and page number emphasis, subject adding, and title and page marking); in locating words within a sub-section or page of text (highlighting); and in locating information nearby in the book's primary structure (the heading hierarchy of Book C). These features will be more completely described and illustrated in the context of Book C in the next section.

Off-line student guides were created and used to introduce students to the different interfaces. Two equivalent lists, each containing twenty history questions, were constructed (an earlier pilot study suggested changes in the length and composition of these lists). In an experiment, 16 eighth-grade students (approximately 14 years old),

TABLE 1
Summary of the attributes of the three books

Book is on paper	A		
Book is on-line:			
"electronic"		B	
"dynamic"			C
User selects questions and enters answers on a computer screen	A	B	C
Book accessed by page numbers	A	B	
Book accessed by chapter, section and sub-section headings			C
Book highlights subject words in text		B	C
Book emphasizes page numbers; Use can add/mark pages		B	
Book emphasizes title; User can add/mark titles			C
User has fast subject index access		B	C
User can add subject terms		B	C
User can match subject patterns			C
User can add subject references			C

in eight groups of two students, looked for answers to these history questions. Each student used Book A, the "paper" book, in a two-hour session on one day. On a different day, each student used either Book B or C, the "electronic" or "dynamic" books, respectively, to find and enter answers for an equivalent list of 20 questions.

Students used two different Xerox research computers: an Alto computer (Thacker, McCreight, Lampson, Sproull & Boggs, 1982) for Book A, and a faster computer, a Dorado (Lampson & Pier, 1980) for Books B and C. Other than by their relative speeds, these two machines could not be distinguished by students. The workstations for both machines consist of a standard alphanumeric keyboard, a mouse for pointing and a black-and-white raster scan screen.

The actions of Book B and C students were recorded electronically to give a detailed description of their use of the browsers. The underlying computer system for each book automatically collected the answers to questions and the latency for each answer, which permitted some performance comparisons. Finally, students answered questionnaires to indicate book preference and problems.

5. Design of a simple dynamic book—Book C

The word "browser" is used below specifically to describe an area on a computer screen with many interrelated smaller areas: a "window" with many subparts or "panes". Tesler (1981) described the browsers that are used to view and modify the Smalltalk system, and these provided a starting point for building browsers for the history textbook and other databases.

Figure 1 shows (in four miniatures) the overall design of the Book C browser. The browser can be divided for purposes of explanation into four major areas, each containing one or more panes. In the *Command Area*, the user selects and reads questions, keeps track of time, and enters answers. In the upper part of the *Subject Area*, the user enters subject terms and selects subjects from the subject index; the lower part of the *Subject Area* displays the subject terms related to the current part of the book displayed in the *Text Area*. The user selects titles in the *Title Area* from

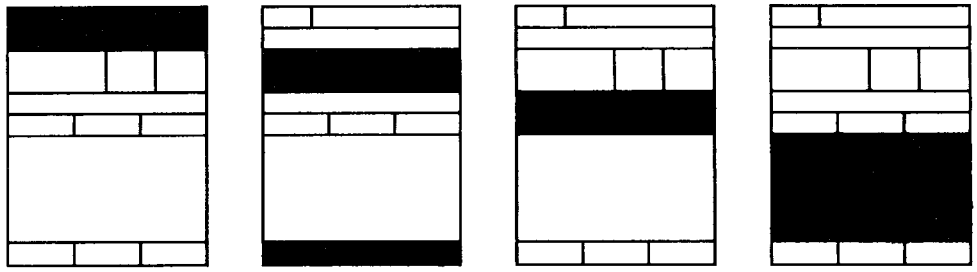

FIG. 1. Book C. Layout of the browser.

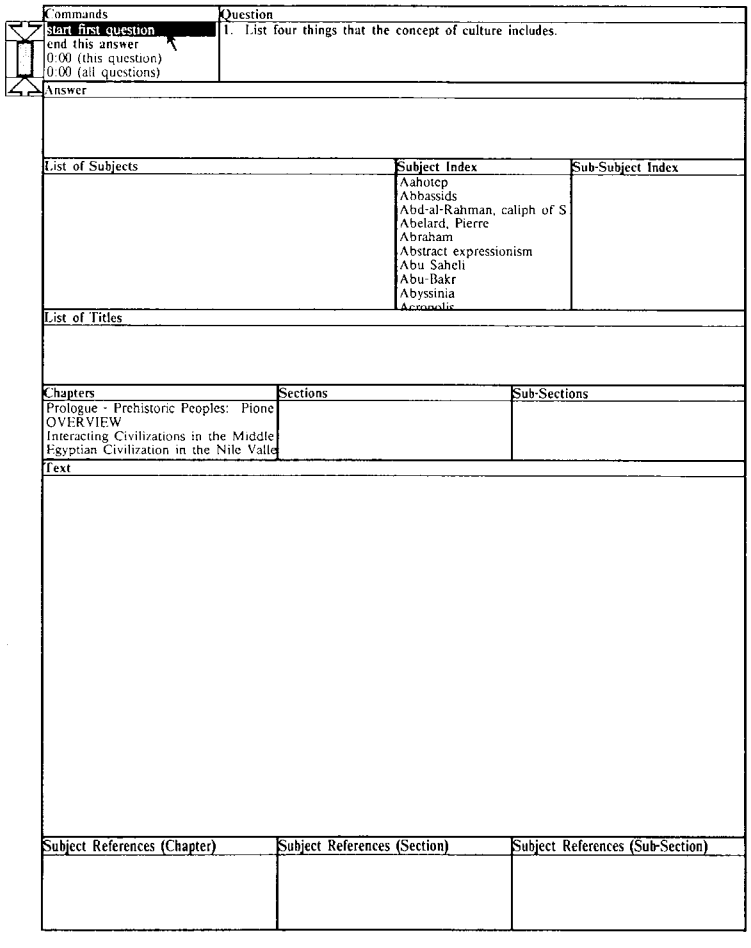

FIG. 2. Book C. An initial view of a browser for a history textbook.

a list of titles or from a three-level heading hierarchy of chapters, sections and sub-sections. The *Text Area* displays a portion of the textbook corresponding to the selection in the *Title Area.*

As the user rolls the mouse across a table, a cursor (a small arrow) moves correspondingly on the screen. The user makes selections by pressing a button on the mouse when the cursor is positioned at a particular item in a pane. Figure 2 depicts an initial view of the browser for Book C, with all panes labeled. The top three panes, *Commands, Question* and *Answer,* are included for the experiment and common to the three browsers for presenting questions and collecting answers. The command *start first question* is selected in the *Commands* area, with the cursor nearby. When an item is selected, it is "complemented" (emphasized by reversing the video display), and related information is displayed in nearby panes, replacing what was there earlier. The result in Fig. 2 is that a question or task ("1. List four things that the concept of culture includes") is displayed in the *Question* area on the right, other panes are initialized, and elapsed times are updated in *Commands.* In addition, a title appears above and a "scrollbar" appears on the left of *Commands,* and for any pane that contains the cursor. A scrollbar indicates which items in the entire list are actually displayed in the pane (indicated by the location and height of the gray rectangle) and enables the user to move the list up or down (by selecting the upward or downward arrows at the bottom or top of the scrollbar).

The particular layout chosen reflects a top-to-bottom and left-to-right flow for an assumed search strategy: ask a question, generate and select useful subject terms, examine references and associated text, possibly return to the subject index with further terms generated from the text, subject references or the user, and eventually enter an answer adjacent to the question. Figure 3 shows the screen after a successful search and answer have been completed. The user typed *culture* in the *List of Subjects* pane, and the system centered the *Subject Index* alphabetically about this term. The user then selected *Culture defined* in the *Subject Index.*

An additional level for this simple subject term was not displayed in the *Sub-Subject Index* on its right, as would have been the case for terms such as *Religion* or *England.* However, a title did appear in the *List of Titles*: *Prologue—Prehistoric People . . . > Prehistoric Pioneers > Work of Archaeologists* (as opposed to page numbers for Books A and B). This title contains three parts, separated by ">"s, that indicate the chapter, section and sub-section headings referring to a particular sub-section of the book (think of titles as the three levels of a hierarchical outline or expanded table of contents for the book). After this title was selected, the corresponding selections were automatically made in the *Chapters, Sections* and *Sub-Sections* panes, and text was displayed in the *Text* area. Exact occurrences of words from the current subject term, such as **culture**, are emphasized ("highlighted") in the *Text* area in boldface; insignificant words such as "the" and "of" are ignored. Related subject terms that refer to the same chapter, section, or sub-section are listed in the *Subject References* panes at the bottom of the browser. After reading the text, the user types an answer in the *Answer* area, and selects *end this answer* in the *Commands* area.

Of course, not all questions can be answered this easily. Questions can require complex search tactics or examination and manipulation of many items of information. Features included in the design of browsers can augment these search and management

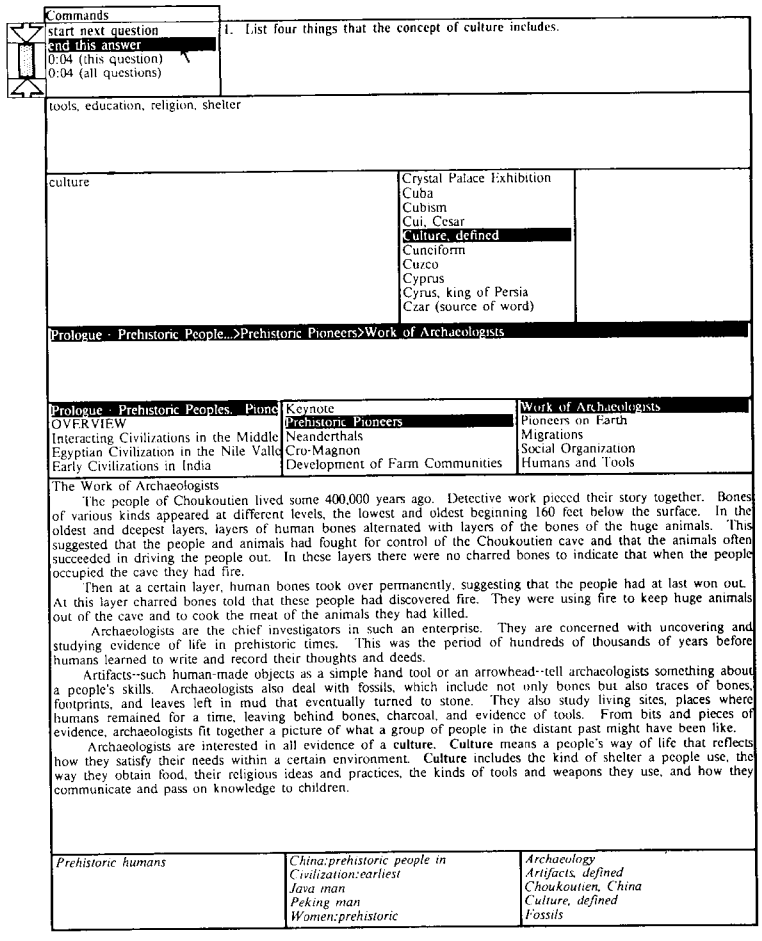

FIG. 3. Book C. A later view of a browser for a history textbook.

processes. Ideally, the set of operations permissible in a browser should match and amplify the tactics used by the searcher [for example, those of Bates (1979)].

On a comparison question (e.g. 2-17: "Briefly summarize and compare the educational opportunities for women that were available in Greece, during the Epic Age of India, in the Roman Republic, and during the Renaissance"), the seeker may access many different places in the subject index and in the main text, perhaps repeatedly. In Book C, the user can see the subject index, neighboring subject terms, a selected subject and its associated list of references, and a portion of the text on the screen, all at the same time. This would be analogous in the paper world to having two textbooks, one book opened to the subject index with the current subject heading circled, the other book opened to one of the corresponding page references. Emphasis in the *List of Titles* could help keep track of which references had been examined (as-yet-unreferenced titles are displayed in boldface), just as checking off the page numbers under the corresponding subject could help the user of a paper book. The

content of headings (in titles in the *List of Titles*, and in *Chapters*, *Sections* and *Sub-Sections*) could also provide an important clue as to whether the text is worth examining or not (in contrast, page numbers provide little information). The Book C user could "add" subject terms (using the "add/mark" button on the mouse) to the *List of Subjects* on the screen for later referral instead of having to probe for the term again; the analogous paper-book action would be to keep a list of subject headings to examine again, and to leave tabs on the appropriate pages of the subject index. After locating a particularly relevant part of the book, the dynamic-book user could "mark" the title, just as the paper-book counterpart could leave a labeled bookmark in the text. Skimming of the text itself could be aided by the highlighting of words and names of interest (those contained in the current subject phrase). However, the reader might miss valuable structure from the order of presentation, as well as interesting details that might have been learned incidentally. Inverted subject references could suggest alternate subject headings (e.g. *Women* or *Education*) that might be more helpful than the original subject terms chosen.

Questions containing dates can present other problems (for example, 2-7: "Who was king of England in 1628 and what significant democratic event occurred?"). Searching for dated events can be nearly impossible in an alphabetical subject index if the date is mentioned only later in the term, e.g. *Concordat of 1801*. Similarly, the subject index might contain no entries under *king*, although there are entries of the form *Charles I, king of England*. Allowing the specification of subject patterns in Book C such as **1801** and **king of England** would allow access where none was feasible before—the system enters matching entries in the *List of Subjects* (other design alternatives might have been to provide KWIC entries or to support free text search). Accessing the subject term *England* successfully will depend on the number and content of its further *Sub-Subject* entries, e.g. *England: representative government in*. If the chosen term refers to a place in the text nearby in time to the desired answer (such as 1625 or 1630), then the user may choose to move backward or forward in the hierarchy (organized roughly by time) to locate the appropriate sub-section rather than to return again to the *Subject Index*.

6. Searching in Book C

Specification and validation of a detailed model of search would be premature given our current state of understanding about search, and the limitations of the experiment. However, by examining the data, we can observe and classify some patterns of use and make suggestions for the next set of explorations. For example, understanding which tactics students used successfully, used inappropriately, or failed to use although applicable, can aid in the better training of searchers. Tactics, as well as positive and negative evidence about the user interface, can suggest ways in which information sources such as dynamic books can be improved to augment rather than hinder the search process. Replaying a student data file can yield a "movie" of how a student actually used the electronic or dynamic book and what he saw on the screen at a given moment. If this were a dynamic paper, then the examples of student behavior presented below could be viewed by the reader as segments from a movie rather than left to imagine from static pictures and dense prose. All of the data files were replayed to aid us in finding problems with the students' use of the books and in understanding

the rationale behind certain patterns of search, especially those that were not obvious from reading the transcript.

This section will present some observations about the use of several tactics in Book C: selecting among alternatives, utilizing the structure of the book, following subject references, and saving and returning to a subject or book location.

Students typically first attempted to probe the subject index with exact words and phrases from the question. For example, Fig. 4 illustrates the course of a simple search,

Question: 1-10. Name an important tool that was probably invented by the Cro-Magnons.
Answer: [typed] *cro-magnons*<↑X> [erased]
List of Subjects: [typed] *cro-magnons*
Subject Index: [selected] *Cro-Magnon humans*
List of Titles:
[selected] *Prologue - Prehistoric People...*>*Cro-Magnon*
Sub-Sections: [selected] *Tools*
Answer: [typed] *burin*

FIG. 4. A simple search for question 1-10.

with two minor variations: typing the subject in the wrong area, and successfully selecting a nearby sub-section of the book from the heading hierarchy. After student #1 (using Book C) discovered that *cro-magnons* had been typed in the wrong area (i.e. *Answer* pane), she erased it and typed it again in the *List of Subjects* area. After selecting the term *Cro-Magnon humans* in the *Subject Index* she selected the associated title reference to a section, selected the sub-section (*Tools*) and entered the correct answer. For this example and later examples, the reader may wish to refer back to Fig. 2 to identify parts of the browser for Book C.

6.1. SELECTING AMONG ALTERNATIVES

When this direct approach did not correspond to a subject term present in the *Subject Index* or was not specific enough, various other tactics were employed. For example, the student might sequence through a list of alternative sub-subject terms provided by the system or terms generated by the student himself. The alternatives under *England* might refer to attributes of or events in England; the terms under *Native Americans* might be a list of individual tribes.

Students sometimes cycled through a list of old, unsuccessful subject terms several times (in the *List of Subjects* or *Subject Index*) rather than trying something different. For example, in looking for information about French government, some students examined all subject headings beginning with "French" and only later, if at all, looked under "France". Training in the application of a term tactic such as "change suffixes" or "use nouns instead of adjectives" could help them break this cycle. Similarly, a semantic, rather than lexical, shift in focus might result in the examination of terms related to "government". Student success in subject access also suffered from taking phrases too literally or ignoring essential content words. For example, in question 1-14, one student found no subject entry for *Britain's National Insurance and Assistance* but then failed to look for *National Insurance and Assistance*. Similarly, in answering question 2-3 about the Thirty Years' War and the Holy Roman Empire, students occasionally omitted *Holy* and thus located information about the *Roman Empire* instead.

Several sources contributed to errors in using lists in the *Sub-Subject Index*. Students forgot to access remaining alternative terms or chose terms in alphabetical order rather than in an order based on content—these are examples of tactical errors. Long lists whose last elements had to be scrolled explicitly into view, or whose elements disappeared at the right edge of the screen, are examples of problems with screen layout, that could possibly be dealt with by using larger screens or compensated for by better training. Modifying the browser to emphasize unreferenced *Sub-Subject Index* terms (as was done in the *List of Subjects* and *List of Titles*) might have encouraged students to access terms in a different order.

When a subject term could not be found, students often tried terms based on other words in the question. Less frequently, the student generated alternatives for the same term. It was clear that most students had a limited repertoire of "Term" and "Idea" tactics (Bates), but a few students were able to generate terms for "English kings" or "voting" (five examples).

Students using Book C could generate a list of alternatives by typing in subject patterns. This was presented briefly in the training sequence as a technique to be used after they had tried more straightforward probes, because it could take up to 60 s for the system to search the index completely. Students did use this technique (8% of the protocols), and many of the tactical and interface errors they made could have been avoided with more training. They sometimes specified a pattern that was too long, e.g. **1450 and 1750**, rather than realizing that a simpler pattern would turn up much of the same information with less chance of failing entirely. A few students tried a pattern search too soon, e.g. **Seven Years' War**; selecting the term directly, *Seven Years' War*, not only is faster, but also positions the subject index to that region of the alphabet. The pattern, especially if misspelled (e.g. the apostrophe omitted) or too complex, may yield nothing. Several students entered a pattern that would have been successful, e.g. **Thirty Years' War**, but they aborted it prematurely when it seemed to take too long with no results.

In the transcript in Fig. 5, student #7 attempted several patterns in Book C to answer the question "Who was king of England in 1628 and what significant democratic

Question: 2-7. Who was king of England in 1628 and what significant democratic event occurred?
List of Subjects:
[typed] *king* [term not present]
[typed] **1628** [aborted; matching terms not present]
[typed] *England*
Sub-Subject Index: [scrolled] 26
List of Subjects:
[typed] **king of england**
[scrolled] -8
[selected] *Charles II, king of England* [no title selected]
[selected] *Edward VI, king of England*
List of Titles:
[selected] *European Nations Explore the ...>*
Power Struggle is Stepped Up...>
Queen Elizabeth I Leads a Strong England
...
List of Subjects: [selected] *Charles I, king of England* [12th king selected]
List of Titles:
[selected] *Representative Government Gro...>*
Parliament Disputes the "Div...>
Charles I is Compelled to Accept the Petition of Right
Answer: [typed] *Charles I, no taxes could be inposed* [sic] *without the consent of parliament*

FIG. 5. Selecting alternatives generated by a pattern for question 2-7.

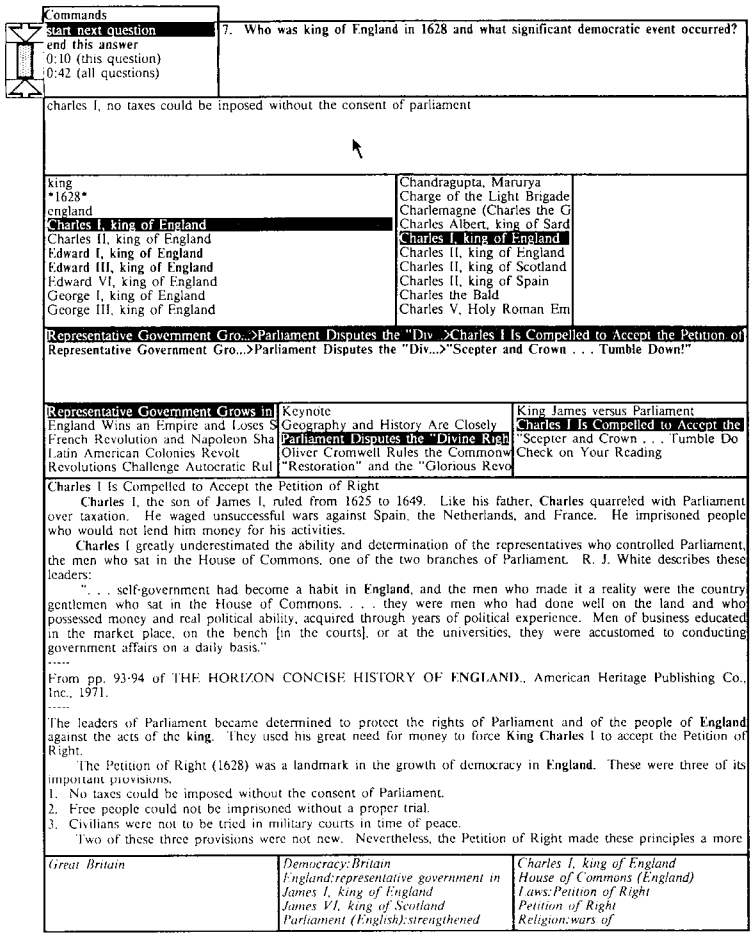

FIG. 6. Book C. A view of the browser for question 2-7.

event occurred?". Figure 6 shows the state of the browser at the end of the question. First of all, *king* did not occur alphabetically in the *Subject Index*. The first pattern **1628** did not yield any results because there are no subject terms such as *Petition of Right (1628)*. The second pattern, **king of England**, yielded a long list of kings including *Charles I, king of England*. Student #7 then sequenced through these in non-alphabetical order, and apparently kept track of kings already tried because only Henry VII was accessed twice in a sequence of 12 kings selected; he may have been helped by the appearance in the *Subject List* of as-yet-unreferenced subjects in **boldface**.

This latter feature was mentioned in the student manual but not explained to students because most lists of title and page references are short and easily managed. The student was eventually successful with his brute force approach of examining all English kings, but could have answered the question more quickly by selecting alternative sub-subjects for *England* (which he rejected earlier), or by more careful

exploration of Book C near the kings he selected. For example, the first king, Charles II, began his rule in 1660, after Cromwell died, but the student did not select this part of the book nor examine parts earlier in the heading hierarchy (organized roughly by time). A little later in the sequence, he selected James I, Charles I's father, who ruled until 1625, and examined the corresponding part of the book, but did not go forward in the heading hierarchy to the next sub-section or section.

Thus, although the pattern match strategy can be helpful, the specification of the pattern and decisions about how to make use of the results need to be taught more thoroughly. Not having access to a feature may be better than using it badly. Errors related to the use of this interface include extra spaces and misspelled terms that the system should be able to detect and report. Showing progress of the pattern match (the system's current term in scanning the index) might help the student to make a more intelligent decision about when to abort. Finally, the resulting alphabetical list of terms is not always the most useful. In a system with more semantic information about persons, the user might like to see the list of kings sorted by another attribute, for example, presented in order of date of birth.

A diagram containing points in an information space and in related index spaces might be one way to represent information, its structure, and possible access paths. Figure 7 diagrams some of the possible points and transitions (applications of tactics) that might be relevant for the question just presented about Charles I. Subject terms on the left refer (are connected) to places in the book on the right. The left-hand side represents selected terms from the subject index; the right-hand side shows the primary order of Book C: a hierarchy of chapter, section and sub-section headings. Note that movements between these spaces can occur in both directions: one can go backward or forward (and up or down) in the heading-order of the book, think of a related subject term after reading a sub-section, or examine the title references under a subject term. In addition, there are other transitions, not visible in the diagram: one could access a chapter directly at the outset or skip over sections; or one could use one subject entry to suggest another similar one without going to the heading space. For readability, subject terms are not presented alphabetically and not all connections between subject index and the book are shown. Line thickness shows degree of term relevance to the particular question, so that subject terms with the thickest lines refer most precisely to the location of the desired information.

Thus, Figs 5, 6 and 7 each provide a different perspective on a search: transcript—what operations were performed by the student and in what order; screen view—how the interface appeared to the student at a particular time; and search diagram—what other options are available in the information space, the structure of the space and what tactics are needed to move in the space.

6.2. ACCESSING THE BOOK THROUGH ITS ORDER

When selecting a subject term did not yield a useful set of references, the student could always return to the *Subject Index* and try another term. However, if the desired information was related in either content or time to the accessed information, another approach was to look nearby in the book itself, using the nested headings of Book C. For example, students may have accessed the sub-subject *representative government in* under *England*, and then selected and read several sub-subjects to reach information about Charles I, as some students did for question 2-7. One student generated names

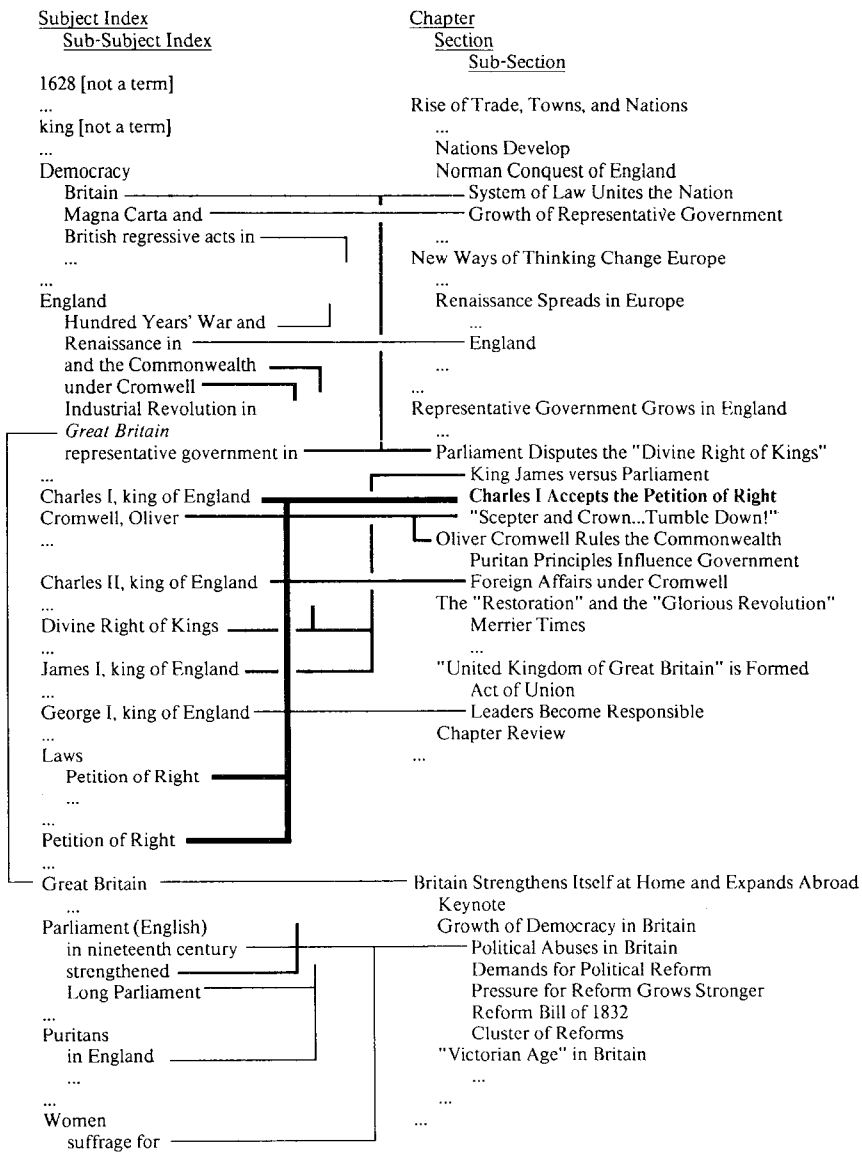

FIG. 7. A search diagram for question 2-7.

of kings (*George* and *James*) to get started. Accessing one or more neighboring sub-sections occurred in approximately 25% of Book C protocols.

In questions involving dates, as in question 2-7 above, students successfully sequenced forward or backward in the book from a nearby date to the target date. Others sometimes continued looking through consecutive parts of the book even though the dates mentioned in that part of the book were centuries away from the desired date. The fact that the order of the book was strongly related to time and that time changed

slowly from section to section was left for students to discover, or remember from previous experience with history books.

A few students using Book C skipped through chapters, a section at a time, and in one case, selected a neighboring chapter. For the most part though, these smaller, "named pages", i.e. sub-sections, were accessed in a sequential order at the lowest level and not at the higher levels of the hierarchy of headings. Depending on the quality of the headings, sections and sub-sections could be skipped over without actually selecting text to be displayed, and depending on how effective the section introductions were as summaries, some detail could be displayed more quickly than in Book B, in which the entire page was displayed. Title references that contained chapter, section and sub-section headings should have been more useful than page references containing only a page number. These former references enabled the student to prioritize access to a list of many titles and to skip irrelevant titles. In Fig. 8, student #7 switched to the chapter on Egypt that followed the chapter containing information about Mesopotamian weapons, then followed the hierarchy to the correct sub-section.

Question: 2-4. Name a weapon introduced to early Egypt about 1750 B.C.
List of Subjects: [typed] *weapon*
Subject Index: [selected] *Weapons*
Sub-Subject Index: [selected] *ancient Mesopotamian*
List of Titles:
[selected] *Interacting Civilizations in...>*
Newcomers Build Empires>
More Conquerors and New Technology
Chapters: [selected] *Egyptian Civilization in the Nile Valley* [the next chapter]
Sections: [selected] *Egyptians Build a Civilization*
Sub-Sections: [scrolled] 3
[selected] *Time of Disorder Was Followed by the Building of an Empire*
Answer: [typed] *horse drawn chariots*

FIG. 8. Selecting chapters, sections and sub-sections for question 2-4.

6.3. FOLLOWING CROSS REFERENCES

If the subject index had contained many cross references (such as "Farming, see Agriculture"), their use in the system would have been more strongly emphasized during student training. Students had problems in utilizing the cross-reference information that did exist in the subject index. Cross references were represented as italicized terms appearing at the end of the *Sub-Subject Index*, for example, *Great Britain* (intended to indicate "see Great Britain") appeared under the subject term *England*, while other sub-subject terms appeared earlier in England's list in a normal typeface (although all are shown here in italics for emphasis). When students selected these cross references, they often did not subsequently use the "add" button on the mouse to add the term to the *List of Subjects*. Perhaps they did not know that it was a cross reference or had forgotten how to add it. Several students selected a cross reference, but then typed it themselves in the *List of Subjects*, which implies that they recognized it as a cross reference. To use a cross reference successfully (as in two of the protocols), a student would have to select the term, add it to the *List of Subjects*, then move the cursor to the *List of Subjects* and select the new term. Multi-step operations such as this to execute a single tactic run the risk of failing because they may result in omitted or improperly executed steps.

Students using Book C had an additional source of cross references available, displayed in the *Subject References* panes at the bottom of the browser. One student even added a subject reference successfully, even though this was not necessary to answer the question. Subject references were intended to provide possible links from the *Text* to the *Subject Index*, especially in cases in which the student located information related to the answer but did not know the proper subject terms to access, and in which the subject terms were not used in the text itself. In a search diagram such as Fig. 7, these would be represented by following the lines from the book on the right to the subject index on the left. These subject references were explained briefly in the training sequence and students were shown that they could scroll the lists of references and add these related terms to the *List of Subjects*. The lists were inconvenient to use because few items were visible, and thus had to be scrolled, and subject phrases were truncated because of limited screen space. The effectiveness of subject references as cross references was probably diminished also by the multi-step "select-add-select" operation referred to earlier. Subject cross references are a potentially valuable addition to a searcher's repertoire of tactics, and should have been better explained to students. For the two questions with which students had the greatest difficulty, subject cross references were successfully demonstrated in two hypothetical searches (Weyer, 1982).

6.4. ADDING AND MARKING

Adding the currently selected subject or subject:sub-subject combination to the *List of Subjects* for later reference (related to Bates' "Monitoring Tactics") was another way in which the user could save time and short-term memory. For one-time access to the subject index, this would be an unnecessary step but, if the user needed to alternate between several different subject terms, this could be advantageous, especially if those terms were not adjacent alphabetically. For example, for question 1-13 ("Name two features of feudalism that were the same in China, Japan and Europe"), the student could have begun by locating *Feudalism* in the Subject Index. It would then be relatively straightforward to select and alternate between the three entries in the *Sub-Subject Index*: *Feudalism*: *European*, *Feudalism*: *Chinese* and *Feudalism*: *Japanese*. Student #3 added these compound subjects to the *List of Subjects*, thereby constructing her own list of terms or filtered view of the *Subject Index*; this was unnecessary because she could have selected the terms easily again, directly from the *Sub-Subject Index*. However, if the student had approached the search by looking first under countries (*Europe*: *feudalism in*, *China*: *feudalism in* and *Japan*: *feudalism in*), the adding feature would be very useful. Returning to examine *Europe*: *feudalism in* would be relatively fast, because the system not only positions the *Subject Index* to *Europe* without retyping, but also selects it because it matches exactly. The second part of the compound term (*feudalism in*) is selected also. Because subject terms remained "permanently" until an explicit "delete" command was used or the next question was selected, marking was not necessary (marked subjects and titles were saved for each question, but because students could not return to work on earlier questions in this experiment, the subjects and titles they had marked were never restored).

Titles in the *List of Titles* could be marked. Titles could originate as a result of a selected subject, or be added later from the Title Index, from the *Chapters*, *Sections*

and *Sub-Sections* panes. Normally, titles were replaced whenever a new subject or sub-subject was selected. Marked titles were kept, however, and new titles added to the list. Some of the observed initial use of adding and marking could probably be classified as either practice or as error in using the "select" button on the mouse (the "add" button was on its immediate right). In most uses of marking, the student did not later return to the marked item.

7. Conclusions

Students learned to use the basic features of the books quickly and with minimal training, but clearly needed more instruction and practice in the more advanced features, such as subject pattern matching and following cross references. Inadequate knowledge about and application of tactics were evident from the protocols of many students for the more difficult questions. Different types of questions encouraged, but did not require, certain patterns of search: for example, questions involving comparisons could be managed easily by using the add and mark functions; questions containing dates could be approached through subject pattern matching and/or by browsing neighboring material through the heading hierarchy; questions not mentioning explicitly, but requiring, the use of a particular subject term, such as "suffrage" or "social welfare", could be answered by utilizing subject references. The fact that students used these features infrequently might be attributed to general lack of usefulness, but more likely to lack of training, some problems with the interface and underlying book, and limited time for the experimental task. For example, simply using a larger display screen, changing the meaning of the mouse buttons, correcting some of the inconsistencies in the original subject index and choosing a more difficult set of questions would give us a clearer focus on search behavior than the present study.

From the questionnaires, we learned that students preferred Books B and C to Book A for the question-answering task and to a lesser extent, for some related, hypothetical tasks. Students also pointed out the design features they liked (such as fast access to subject terms, term highlighting and simultaneous access to subject index and text) or disliked (small typeface) in the different user interfaces. Analysis of group performance data revealed a significant, though slight, speed advantage for Books B and C over Book A, and no difference with respect to answer correctness, A result of "computers are faster or better than paper books" is not generalizable from the small, exploratory experiment presented here; nor does it appear a particularly fruitful approach for future evaluations of dynamic book designs or for understanding the search process.

This experiment demonstrated the feasibility of using dynamic books for the particular educational task of seeking information to answer questions. Experience with dynamic books in other learning situations will suggest other opportunities and problems, such as the problem of how a dynamic book might, for example, help a student to ask better questions, to find, interrelate or remember information, or to synthesize better answers. Instead of using the book as an encyclopaedia, how could it be used as a dynamic textbook by the teacher, a group of students or an individual student?

A history book, based on a published, paper version, was used in this work. How would someone read and search through a book that was conceived and written

originally as a dynamic book? It would not only include pictures and animated maps, but also be represented as a knowledge network of related events and associated text commentary. Access to the book could be augmented by free-text search, timelines, geographical and political maps, an improved subject index or concept hierarchy, and other query styles. How would the interface commands or layout change if, instead of a history textbook, the "book" were a physics simulation, a database of scientific observations, one's personal files or the ongoing transcript of a group discussion? As part of a dynamic library of interconnected books, a dynamic book would offer other directions to explore.

Little training was offered in the use of the browser and in the application of tactics. Formation of an explicit model of tactics and their realization through the browser could aid in evaluating the strengths and weaknesses of interface designs. If the system itself incorporated such a model, it could offer tutorial aid during the search process.

Communication, cross-fertilization and co-operation among different subject disciplines offer new perspectives on these problems and increased leverage for their solution. Integrating the important contributions of designers of database and artificial intelligence systems, book and newspaper publishers, librarians and editors, and educators and psychologists is, however, itself a large search task, indicative of the limits of our vocabulary and current approaches.

The technology surrounding dynamic books will continue to improve, to become more available, and to out-distance our ability to use it effectively. Information systems will proliferate and make more information available, but how are we to evaluate the accessibility of the information in these systems, and influence the design of true information services? In whatever guise or form, dynamic books should give mastery to individuals over an information environment that otherwise appears intimidating and complex.

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