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ABSTRACT

This field experiment begins to build a theoretical framework for exploring the effects of media characteristics on subjects' understanding and integration of information. Students in two eighth-grade science classes wrote term papers with one class using a print encyclopedia and the other an electronic encyclopedia to conduct their research. A third class, taught by the same teacher, was not assigned the term paper and acted as a control group. Measures of horizontal knowledge (breadth of knowledge on the topic) and vertical knowledge (depth of knowledge on the topic) were collected from pre- and posttests, as well as from teacher assessments of the final papers. The horizontal and vertical knowledge measures were designed to tap the effects of basic characteristics of the two media systems on the way in which the subjects used them. Because of the nature of the system, students using the videotex system were expected to score highest on horizontal knowledge, whereas print students were expected to perform best on measures of vertical knowledge. Results support the first hypothesis with students in the electronic encyclopedia class scoring significantly higher on measures of horizontal knowledge. However, teachers also scored the electronic encyclopedia student papers higher on vertical knowledge. This exploratory study concludes that efforts to link specific media characteristics to dependent measures of subject understanding or learning is a fruitful approach for research on the effects of new technologies. An 11-item bibliography and 3-point scales for each of the dependent variables (appearance, vertical, and horizontal knowledge) are included. (Author/THC)

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Biases of Communication Systems:
An Exploratory Approach to Studying New Communication Technologies

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Biases of Communication Systems:
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This field experiment begins to build a theoretical framework for exploring the effects of media characteristics on subjects' understanding and integration of information. Students in two eighth-grade science classes wrote term papers with one class using a print encyclopedia and the other an electronic encyclopedia to conduct their research. A third class, taught by the same teacher, was not assigned the term paper unit and acted as a control group. Measures of horizontal knowledge (breadth of knowledge on the topic) and vertical knowledge (depth of knowledge on the topic) were collected from pre- and posttests, as well as from teacher assessments of the final papers. The horizontal and vertical knowledge measures were designed to tap the effects of basic characteristics of the two media systems on the way in which the subject used them. Because of the nature of the system, students using the videotex system to access an electronic encyclopedia were expected to score highest on horizontal knowledge, whereas print students were expected to perform best on measures of vertical knowledge. Results support the first hypothesis with students in the electronic encyclopedia class scoring significantly higher on measures of horizontal knowledge. However, teachers also scored the electronic encyclopedia student papers higher than the print student papers on vertical knowledge. This exploratory study concludes that efforts to link specific media characteristics to dependent measures of subject understanding or learning is a fruitful approach for research on the effects of new technologies.

In his innovative work on the biases of communication, Innis suggested that the character of knowledge within a given society is largely a function of the characteristics of its dominant medium (3). Though much of his discussion was based on a historical survey of media examples from ancient cultures, he articulated a general paradigm to guide the study of contemporary media. He selected specific points in time when new media were introduced into existing cultural milieus and attempted to show how the biases of new media resulted in changes in the character of knowledge within a particular culture. For Innis, character of knowledge is a prime factor in the culture's evolution. For example, in discussing the shift from papyrus to parchment during the Roman Empire, he suggested that this "extension" of the medium brought about significant social and cultural changes for the Western world:

Christianity exploited the advantages of a new technique and the use of a new material. Parchment in the codex replaced papyrus in the roll. The parchment codex was more durable, more compact, and more easily consulted for reference....Convenience for reference strengthened the position of the codex in the use of the scriptures or of codes of law. The codex with durability of parchment and ease of consultation emphasized size and authority in the book. Verse and prose which had been read aloud and in company to the third and fourth centuries declined. Reading without moving of the lips introduced a taste and style of its own. The ancient world troubled about sounds, the modern world about thoughts. Egoism replaced an interest in the group (3, p.14).

Thus, according to Innis, the biases or characteristics of the dominant medium (parchment) facilitated increased convenience, accessibility, and durability of the scriptures. As a result, it contributed to the spread of Christianity and of solitary rather than social reading. The characteristics of the medium interacted with the cultural and historical context to bring about qualitative changes in the character of information and knowledge.

Innis' discussion is panoramic. He examines the history of dominant media in their cultural settings from ancient times to the twentieth century. His writing abounds with general statements regarding the causal nature of the relationship between media extensions or technological innovations and cultural change or evolution:

I have attempted to show that sudden extensions of communication are reflected in cultural disturbances. The use of clay favored a dominant role for the temples with an emphasis on priesthood and religion. Libraries were built up in Babylon and Nineveh to strengthen the power of monarchy. Papyrus favoured the development of political organization in Egypt (3, p.31).

This passage continues to cite major media extensions, century by century, bringing the reader up to the present day when, "...new methods of communication weakened the worship of the book and opened the way for new ideologies" (3, pp. 31-32). Innis considers these media extensions as factors which contribute to social and cultural reorganization.

Our purpose is to adopt Innis' approach in studying new technologies; that is, to examine the characteristics or biases of a communication system as predictors of the resulting character of knowledge among users. However, our discussion will be limited to examination of only one new communication system in only one situation. Unlike Innis, we are not writing history, rather we are attempting first, to build a theoretical approach to the study of new technologies on the basis of his insights and second, to test its efficacy in the context of a field experiment.

A meta-analysis of media studies identified a clearcut pattern in research responding to the introduction of new media (10). This study reported that the first questions applied to the study of new media tend to focus on limited, atheoretical topics, such as health effects, descriptions of use patterns, and the extent of displacement of established media.

Similar constraints have characterized the study of new technologies, resulting in a call for more theoretically based approaches (7).

The differential cognitive impact of communication systems is not an entirely new concern in the field of media study. In their work on the cognitive effects of educational media Olson (5) and Olson and Bruner (6) discussed research on the effects of mode of presentation as a predictor of knowledge acquisition. Olson summarized the findings in this line of research as follows: "The impact of technologies both ancient and modern on children's learning is either negligible or unknown" (5, p.6). His solution was to develop a theoretical framework: "specifying how information is structured by various symbol systems, how that structuring is influenced by the various media... and the psychological consequences of relying on these structurings (5, p.10).

Salomon (9) expanded on the work of Olson and Bruner. His interests focused on the unique combination of symbol system and technology that characterizes a particular medium, such as a map or a painting. Like Olson, he proceeded under the assumption that the dominant media research paradigm suffers from major limitations. He said a new theoretical framework must be:

first, ... one that does not define them (media) as sheer technologies or invariant entities and that relates them to thinking and learning. Second, it calls for the identification of those characteristics of media that differentiate among them and thus are potentially important sources of influence. Third, it requires a more theoretical orientation to research on media (9, p.10).

The following field experiment, comparing the use of two communication systems--electronic and print versions of a standard encyclopedia--was designed as an effort to address the limitations of traditional research articulated by Salomon and Olson.

Hypotheses

We were interested in testing the efficacy of Innis' notions regarding the implications of different media characteristics or biases for the resulting character of knowledge among users of particular media systems. As a result, research hypotheses cannot be specified without first presenting a detailed specification of 1) the task for which the medium was used and 2) the characteristics of the respective media systems. Our hypotheses are directly related to careful examination of how a given medium works--what the individual must do to use it to fulfill the requirements of the task at hand.

Characteristics of the Task

The eighth grade students involved in the field experiment were assigned the task of conducting research on a science topic and then writing a term paper about it. The basis of their research was to be a standard encyclopedia. A basic characteristic of using an encyclopedia, particularly for this task, is directed searching within a set of boundaries created by the user.

Characteristics of the Print Encyclopedia

Our observations of student use of the print encyclopedia suggested that its most striking characteristic is its potentially intimidating physical presence. Use of the multiple-volume set requires several steps: first locating it in the library stacks, then finding the proper volume for the topic being researched, and finally turning to the appropriate entry. Also, we noted that its alphabetical presentation makes cross reference searches across articles, here referred to as horizontal searches, cumbersome for users who would have to locate all of the necessary volumes sequentially. Within the individual article, however, the encyclopedia text tends to present a hierarchical or vertical structure of knowledge; that is,

it begins with general statements, permitting the user to get a "quick fix" on the topic, and then moves into more specific and detailed information. Because of the structure of this presentation, and because the user can quickly skim over the entire article on the page, there is likely to be a tendency on the user's part to view the article as complete in and of itself. It gives the impression that it stands alone as a source of information on the topic. In addition, encyclopedia text uses a dense and terse writing style, making note-taking slow.

Characteristics of the Electronic Encyclopedia

Observations of salient characteristics of the electronic version of the encyclopedia differed from those of the print version in several important ways. Probably the most significant difference is that before the individual can use it, he must master the videotex system--log-on procedures, system commands, keyboard conventions, and so on. Having entered the electronic encyclopedia, however, one may remain physically stationary at the terminal, allowing his fingers to do the walking. For example, conducting a horizontal or cross reference search is simply a matter of typing in the new term, rather than physically getting up to find another volume and hunting through its pages. Also, such systems may allow users to obtain printouts of their disk files recording all the searches and text obtained during a session, thus alleviating the pressure for note-taking and careful perusal of the information encountered during the search. One may simply wait until he receives his printout to read the information. In the system studied here, the printouts were exact records of what appeared on the screen; users could not simply request a printout of any one article or section of an article. Furthermore, because of the physical

limits of screen capacity, users see only one screen of information at a time. They cannot skim an entire entry as with the print encyclopedia. In addition, articles were frequently interrupted by submenus, so that the user could not simply run straight through an entire article. When a submenu appeared, the system paused for the user to make a selection. This feature of the system illustrates one of the most important characteristics of the electronic encyclopedia. Using the electronic encyclopedia demands interaction with the user. The system waits for a response before proceeding to another search or putting up another screen of information. The user must actively request information and additional searches in order to get them.

These differences in the two information systems led us to our research hypotheses regarding expected differences in the resulting character of users' knowledge structures. The concept of knowledge structure refers to the way in which information is integrated and organized by the user. We hypothesized that if Innis is correct, the differences in the characteristics of the two media systems should lead to differences in users' knowledge structures. Thus, we tested Innis' claim that media system characteristics can determine the resulting character of knowledge among users.

Because of the unique characteristics and demands of the systems, we expected users to adopt different strategies to search for information, that is, to perform the task at hand. We reasoned that the search strategies facilitated by the respective systems should contribute to the resulting structure and organization of the information encountered. Therefore, because the electronic system facilitated horizontal or cross reference searching behavior, we hypothesized:

H1--Individuals using the electronic system should demonstrate more horizontal knowledge structure within a general content area than would print subjects. Both videotex and print users would demonstrate more horizontal knowledge structure than individuals in the control group.

Because the print version, on the other hand, presented a more vertical knowledge structure and because users' horizontal searches were constrained by the physical inconvenience of having to pull additional volumes off the shelves, we hypothesized:

H2--Print only users should demonstrate more vertical knowledge structure on their selected topics than students using the electronic system, with control subjects demonstrating the least evidence of vertical knowledge structure.

Finally, the limits of a single, short media encounter, an encounter related to a particular task, should be reflected in limits in the effects of media bias upon the structure of knowledge. The recognition of limits does not represent a departure in theory from Innis' paradigm, but rather represents a recognition of the limitations of a single, carefully circumscribed media experience.

The encyclopedia, in fact the entire videotex system, consisting of a variety of information services, can be conceptualized as structured in a more general way than the dichotomous distinction between horizontal and vertical knowledge structures, namely as tree structures. The classic example of a tree structure is the classification of animals and plants into species, genera, and so on. Tree structures are widely used to organize data bases. In videotex systems, a tree appears as a series of menu choices: each menu choice leads to yet another menu, until the specific piece of data desired is located. The encyclopedia service itself was arrived at by descending through several general menus, which is equivalent to choosing a smaller branch off of each larger one.

The tree can be conceived of as more general than vertical or horizontal knowledge in that the tree can encompass both. Vertical knowledge can be conceptualized as moving up and down a tree (for example, species to genus to family), while horizontal knowledge can be conceptualized as moving across the same level (for example, from genus to genus). There is empirical evidence that learning to use a tree in one manner--horizontally or vertically--does not readily generalize to the other manner. Restle (8) demonstrated that subjects could be trained to use a tree in a predominantly horizontal or vertical manner. He gave individuals examples of using trees that stressed the horizontal or the vertical. (The examples used the structure of the army and a corporation.) Subjects took more time to answer questions that required thinking about a tree in the manner for which they were not trained. We propose that the searching strategy adopted by the user as a function of the media system to which he is exposed will be limited by the demands of the task at hand, writing a science term paper. Therefore, the more directly relevant vertical and horizontal knowledge structures, may in fact be altered, but broader, more generalized modes of organization, such as trees, will not be affected. Thus, we hypothesized:

H3--No differences will result among the three treatment groups on measures assessing organizing information into three structures.

Method

The field experiment involved three eighth grade science classes. In one, students used a commercial videotex service offering an electronic version of a standard middle school encyclopedia to conduct research for a

science term paper. In a second class, students were assigned the science term paper but used a print version of the same encyclopedia, and in the third class, which acted as a control group, no term paper was assigned. All three classes were taught by the same teacher and involved the same science curriculum (except for the term paper task). The classes met back-to-back during the school day.

Our primary interest was in the resulting character of knowledge associated with use of either traditional print material or an electronic information delivery system. The control group was designed to provide comparisons with baseline data on classroom learning that occurred independently of the month-long instructional unit on writing term papers.

A pre-test was administered by the teacher in all three classes. The instrument included items on using reference materials for conducting research and cognitive ability. Following the pretest, both experimental groups (the print and the electronic encyclopedia groups) received instruction from the classroom teacher and the school librarian concerning how to use the library. They completed several written exercises on the card catalog, bibliographic citations, reference materials and so on.

In addition, the electronic group learned how to use the videotex service. The teacher discussed the system and demonstrated how to use it, and students received instructional workbooks with step-by-step procedures to follow for logging on and off the system. They had a minimum of four scheduled computer sessions (about 20 to 30 minutes each) during which they were to conduct their primary research on their selected science topics.

After completing their research, students in the two experimental treatment groups wrote their term papers. Using a posttest instrument, we repeated the measures on using reference materials for research purposes.

Measures

Dependent Variables

Dependent measures are derived from the constructs of vertical and horizontal knowledge structures. A brief conceptual explication of these constructs is necessary. Reading through each individual encyclopedia entry sequentially represents a vertical information searching strategy. Rather than crossing over to horizontal or cross reference entries, the user relies on the vertical presentation of information dictated by the medium. The notions of horizontal and vertical knowledge structures are derived from thinking about students' science topics from two different perspectives, first in a wider context, across a general area of information, and second in some sort of specialized knowledge hierarchy. An example might help illustrate this distinction. If a user looked up the science term "monkey," the horizontal information searching strategy, facilitated by the electronic system, might lead him to look up "rhesus," "Africa," "mammal," "human," and so on, in no particular order without a systematic plan. The vertical searching strategy, facilitated by the print encyclopedia, would instead present the user with a hierarchical discussion of "monkey" within a rather narrow context of species, genus, and family. He would encounter a specialized and systematic presentation of the animal and its relationship to other mammals, within the context of one unified article. Because of the inconvenience of conducting cross reference searches, he would probably be less likely to seek out related terms. In part, this result is attributable to the physical difficulty of doing so, but in part it is also attributable to the physical traits of the information presentation provided by the medium. Each article appears to be a complete entity in and of itself.

Our operationalizations of vertical and horizontal knowledge structures involved two different approaches. The first set of measures was constructed from subjects' posttest responses. The posttest assessment of vertical knowledge structure was designed to be closely related to the assigned task of using the encyclopedia for research purposes. Following a detailed example showing students how to proceed, based on a topic unrelated to science, students were instructed to select one of six science terms listed and:

Imagine that you have looked up your science term in the encyclopedia. Imagine that you are looking at the article right this instant. Now write down what you think the article would talk about, what it would say. You don't need to use complete sentences.

This first measure resulted in a count of the total number of phrases a student reported describing what the encyclopedia article would say. We considered this to be a measure of the vertical knowledge structure, or the depth of information students reported. We expected the lowest number of phrases for the control group, and the highest number of phrases for the print encyclopedia treatment, with the electronic group falling in the middle.

The posttest assessment of horizontal knowledge structure, again designed to be closely related to the task students performed, also involved an encyclopedia-related task as follows:

Often you don't find quite the right information just by looking up the one term. Let's say you really want to find out about the topic. What other specific terms would you look up in the encyclopedia to find out more?

A detailed example was again provided. Students used the same science term they had selected for the first encyclopedia task.

The measure derived from the second task, using the same science term selected for the first task, gave us an assessment of students' horizontal knowledge structures. It presented us with the total number of related or cross reference encyclopedia searches the student could try. As with the vertical knowledge measure, we expected the lowest scores for the control group. But the highest scores for the horizontal knowledge structure, we hypothesized, should appear in the electronic encyclopedia group because the characteristics of the media system facilitated this information searching strategy. We expected the print group to fall between the control and the electronic groups on this measure of horizontal knowledge.

Our second approach to the measurement of vertical and horizontal knowledge structures is based on a different type of measure--assessments of students' term papers. We posed the question: How were students' knowledge structures actually manifested in their final product, the term paper? How did the unique biases of the respective media systems affect the integration of the information encountered into their resulting knowledge structures? This approach differs from the encyclopedia posttest task in important ways. First, it is unobtrusive; second, it is much further removed from the task at hand--using the media system to gather information. It taps the resulting integration and organization of the information encountered by the user.

The term papers (without students' names) were assessed by four eighth grade teachers at the middle school. They conducted a holistic assessment (4) of the individual papers on a variety of dimensions, three of which are relevant here:

1. Appearance
2. Scientific knowledge
3. General knowledge

The first measure was included to test for the possibility of a Hawthorne effect among the videotex subjects. We expected no group differences between the videotex and print subjects on this measure. The final two measures on scientific knowledge, a measure of vertical knowledge structure, and general knowledge, a measure of horizontal knowledge structure, were included for our purposes in examining the character of students' resulting knowledge structures (for definitions, see Appendix A). Though these measures approach knowledge structures in a different manner from the post-test measures, we again expected the print treatment group to score higher on the vertical knowledge measure, whereas the electronic group would score higher on the horizontal knowledge measure.

Holistic assessment (4), a procedure similar to content analysis, typically follows a standard procedure. First, all evaluators meet and agree upon a rubric, a set of guidelines to follow for scoring papers. In this case, the four teachers met and discussed the dimensions to be scored. For each score of each dimension (each was a three-point scale), a definition was written and model papers representing that score were selected. The model papers were then available for consultation throughout the scoring process as checks on the evaluator's work. In this case, the evaluators reached a .80 level of agreement before proceeding to assess the papers.

In order to measure an understanding of tree structures, students were given the following task:

On the next page is a list of words and phrases that you are to organize. The point is to organize the terms into groups. Smaller groups must be part of larger groups. Make as many different groups as you can. When you're done making groups, show the organization in a picture. The picture should look something like the picture below. Of course, it doesn't have to look exactly like the example.

The example used plants and animals and demonstrated how to organize them into classes and subclasses. Students were then asked to make a tree involving classes and subclasses of popular team and individual sports. Each term was scored as correct if it appeared directly underneath its appropriate class or subclass. The number of correct locators was totaled for each person to arrive at a tree score.

This measure and the encyclopedia measures were designed to match closely the type of knowledge structure considered. Hence, the tasks are somewhat unusual. All questions were pre-tested, in a different school with similar demographic characteristics--largely rural and blue collar--and all questions were discussed extensively with teachers involved in the project.

Independent Variables

In the following analyses, three independent variables are of interest: cognitive ability, pretest scores on the encyclopedia-related measures of vertical and horizontal knowledge structures, and treatment group.

Cognitive ability and pretest scores were included in order to remove the variance explained by those factors before introducing treatment group to the model. It was believed that both were likely to be strong predictors of performance on measures of vertical and horizontal knowledge and should, therefore, be included. The cognitive ability scale was based on a series of problems designed to measure the students' ability to categorize: students were instructed to cross out the word that did not belong in a list. The items for the scale were taken from an instrument designed and tested by Whimby and Lockhead (11). The pretest scores for the encyclopedia measures were identical to the posttest dependent measures explained above on vertical and horizontal knowledge. Treatment group refers to the control (N=25), print (N=32), or videotex (N=27) science class.

Results

The data were analyzed using analysis of covariance in order to remove the variance explained by cognitive ability and pretest scores before introducing treatment group to the model. The dependent variables are the posttest measures of vertical and horizontal knowledge structures, as well as the three term paper measures--appearance, scientific (vertical) knowledge, and general (horizontal) knowledge, and the tree structures. The central question is whether significant differences in vertical and horizontal knowledge structures will emerge as a function of treatment group, as predicted, after controlling for cognitive ability and pretest scores on the dependent measures.

Table 1 about here

Consistent results appear for both the posttest ($F_{2,74}=7.25, p<01$) and the term paper ($F_{1,47}=5.22, p<05$) measures of horizontal knowledge structure. As predicted, in both analyses the videotex treatment group performed significantly better than did the print group, and both experimental groups scored higher than did the control subjects on the posttest measure.

For vertical knowledge structure, the posttest measure did not yield significant results. The F-test, after removing the variance attributable to the covariates, is not significant. The vertical knowledge structure measure, taken from the holistic assessments of the term papers, is significant ($F_{1,47}=7.60, p<01$), but the direction is the reverse of the prediction. Videotex students scored significantly higher than did the print group on this measure.

Finally, as predicted, results on the measure of students' understanding of the more generalized information structures of trees, demonstrate no significant differences among treatment groups. All students seemed equally competent at performing the tree task.

Discussion

The results of the analyses presented above yielded some support for Innis' approach to studying new media. Media biases can affect users' resulting knowledge structures in specific ways. Horizontal knowledge structure, for both the posttest and the term paper assessments, was enhanced by use of a media system that facilitated horizontal searching strategies. Students who mastered the videotex system and exploited its biases--power and convenience--demonstrated consistently more horizontal knowledge structure in relation to the task at hand. They reported significantly more cross reference searches in the encyclopedia posttest task, and they integrated the information encountered while using the system into a broader (more horizontal) context, as demonstrated by the group differences in the holistic term paper assessments.

Hypotheses concerning the measures of vertical knowledge were not supported. In the case of the posttest vertical knowledge structure measure, group differences were not significant. Print subjects, contrary to our prediction, demonstrated no greater vertical knowledge than did the videotex or control groups. It may be that the task was too difficult for many students. The teachers had warned us that writing a hypothetical encyclopedia article would be very difficult for some of the eighth grade students. Only the brighter ones, they said, would be able to do it. After removing the variance attributable to cognitive ability and pretest scores, treatment group did not account for a significant amount of variance. For

the holistic term paper assessment, however, significant group differences appeared, with videotex subjects demonstrating more vertical knowledge structure than print subjects. This finding runs directly counter to our hypothesis.

In retrospect, this result may be attributable to the fact that videotex subjects could obtain printouts of their transactions while using the electronic encyclopedia. Analyses of these buffer files suggest that though videotex subjects did considerable crossing over (horizontal searching) from one article to another, they also tended to print out the full (vertical) article before doing so (Eastman & Agostino, 1984). Thus, not only did they benefit from the system's facilitation of horizontal searching, they also obtained full vertical presentations of the articles searched to peruse at length and to rely on later when writing their term papers. Being able to obtain printouts was another media bias of the videotex system, but one which was adapted by students to meet their needs in responding to the demands of the task at hand. In fact, observations of students using the electronic encyclopedia reported that in their eyes, successful completion of the task was obtaining as large a stack of printout as possible (1). Hence, they requested full articles of all their searches possibly resulting in increases in vertical knowledge structure. In addition, the differences in the kinds of measures being analyzed here must also be considered. The term paper measure is derived from students' final products, the papers they wrote following the encyclopedia (either print or electronic) research. The process of writing intervenes between gathering the information and submitting the final term paper. It may be that something in this process of organizing and structuring the information gathered helped the student grasp the vertical knowledge structure of the selected topic.

No evidence of a Hawthorne effect emerged. There were no significant group differences on holistic assessments of term paper appearance, as predicted.

Finally, the results of the tree measures supported our hypothesis, testifying to the limitations of acquiring knowledge structures from media systems. No group differences appeared. Observational data confirmed our expectations in relation to this issue. Students never asked questions about how the computer software worked, questions that would not have been relevant to the task at hand (1). In fact, the computer software worked like a tree, but this structural feature did not seem noteworthy to the students. Thus, the effects of media biases were limited to measures directly related to the task at hand and were not generalizable to broader, more abstract principles of the organization of information.

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Appendix A

Appearance

Appearance was assessed on a three-point scale as follows:

1. paper appears of little significance to the author, no title page and probably no bibliography is included; these papers may be messy with errors scratched out; they may be written in pencil.
2. paper is generally neat with only a few errors; it has a title page and a separate bibliography.
3. paper is either neatly typed or written in ink; few errors are present; it has a title page and a bibliography.

Scientific (Vertical) Knowledge

Scientific knowledge was assessed on a three-point scale as follows:

1. little or no information that does not come from daily life; little that describes how things work or how animals do things.
2. information but little technical information; a simple, spotty description; little or nothing in the way of definition of terms.
3. more information but particularly more complete or detailed information and more use of definitions of technical terms; descriptions are more thorough with some detail and analysis.

Breadth of (Horizontal) Knowledge

Breadth of knowledge was assessed on a three-point scale as follows:

1. little information that is not basically scientific; mostly opinion or from daily life; unsupported opinion.
2. more extra information but detail is largely personal experience or observation; little or nothing from different areas of science in addition to personal experience.
3. detailed information from at least one area that is not only personal observation or experience and also is not central to the scientific aspect of the topic.

TABLE ONE

Effects of Using a Print or Electronic Encyclopedia
on Knowledge Structures
Controlling for Cognitive Ability and Pretest Scores

	No Paper (Control)	Print Encyclopedia	Videotex Encyclopedia
Vertical Knowledge Structure (Posttest)	6.53	7.40	6.89
Horizontal Knowledge Structure (Posttest)	6.57**	8.25**	10.15**
Vertical Knowledge Structure (Term Paper)	----	1.81**	2.21**
Horizontal Knowledge Structure (Term Paper)	----	1.72*	2.07*
Appearance (Term Paper)	----	1.93	2.31
Tree Knowledge Structure	20.02	19.53	20.57

* p<.05

** p<.01

Scores are means for each group adjusted pretest scores in the cases of the posttest measures, and cognitive ability.