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The Effects of Concept Mapping on the Searching Behavior of Tenth-Grade Students

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A qualitative study addressed the effect of concept mapping on the searching behavior of tenth-grade students engaged in research projects based on their instruction in a classroom-based genetics unit. The setting was an automated library of a private American school in Europe. Ten biology students were chosen by purposive sampling. Selection criteria, monitored by user profiles, included student age, computer experience, native language, grades, and test scores. One group used concept mapping, while the other received the same classroom instruction without mapping. Data on searching behavior were collected using think-alouds, interviews, debriefing, and journals. Calculations based on Bayesian statistics and the Fano measure from information theory were triangulated with qualitative analysis of data. While the entire research process, as defined by Kuhlthau's model, was examined to include stages from pre-focus formulation to writing the research paper, this article centers on the information search. Fano's information measures showed there was a greater probability that concept mappers will use print rather than electronic means, that they will search in SIRS rather than the OPAC, and that in electronic searching they will use subject heading rather than keyword. In print, as opposed to electronic searching, measures showed mappers applied a larger number of search terms, employed opening moves, re-formulations, search operations, and relevancy judgments more often and executed more depth than breadth searching. In all cases probability measured at least half a nat (one nat equals 2.718), indicating chances were approaching twice as likely that searchers exhibiting these characteristics in print indexes will be mappers. Larger differences between the groups emerged in electronic searching, where mappers spent less time. Quantitative data verified mappers were more thorough and efficient, reformulating by shifting synonyms and moving from general to specific search terms and terminating searches to read rather than when they depleted their search terms. Stronger focus formulation emerged as the most important determinant of searching behavior. Further research is recommended to replicate the study with a larger sample, using information theory as an alternative to classical statistics in hybrid qualitative-quantitative studies.

The Problem

The paradox confronting students-as-information searchers is that they must ask for what they do not know. Without a conceptual framework buttressed by enough knowledge to generate search terms, students have difficulty locating and recognizing relevant information. To build a knowledge base, however, new knowledge must be integrated with prior knowledge (Ausubel

1963). A lack of knowledge results in inability to ask for what is needed and an inability to determine the relevance of what is found. Will concept mapping, used in the classroom as a heuristic learning device, affect the information searching of ten students? Will it help searchers to overcome an anomalous state of knowledge (Belkin, Oddy, and Brooks 1982)? This study follows ten students from a classroom-based unit on genetics to a library-based research assignment and is based on the belief that inadequacies in searching vocabulary are symptomatic of poor concept formation. Is it sufficient to examine searching behaviors as isolated phenomena without benefit of the context of the research process?

The question of whether one instructional method is more effective than another is, in itself, a problem in school library research. A content analysis of the research literature by Eisenberg and Brown (1992) revealed that many of the assumptions upon which we have based library programs have gone untested. The authors identified four areas for future research: (1) the value of instruction in library and information skills; (2) the skills curriculum should emphasize general information problem solving research and research processes; (3) these skills should not be taught in isolation; (4) innovative instructional methods and technologies can enhance the teaching of information skills. Eisenberg and Brown also concluded that models that define the research process had not been verified.

The Process Model for Research (Kuhlthau 1986), verified in longitudinal studies, has filled this gap over the past decade and is used as the framework for structuring the design of this study. Table 1 outlines the model in terms of the six stages: task initiation, topic selection, pre-focus exploration, focus formulation, information collection, and search closure, which is followed by the writing.

Table 1. ***Kuhlthau Model of the Search Process***

Stages

Task Initiation	**Topic Selection**	**Prefocus Exploration**	**Focus Formulation**	**Information Collection**	**Search Closure**	**Starting Writing**
Feelings	uncertainty	optimism	confusion, frustration, doubt	clarity	sense of direction/confidence	relief
Thoughts	ambiguity----------->specificity----------->increased interest					
Actions	seeking relevant information----------->seeking pertinent information					

Kuhlthau's model documented student progress and how it impacts their confidence and final products. Both thoughts and feelings were considered as searchers advanced from seeking relevant information to seeking pertinent information. Increased confidence correlates with more focused papers and higher grades (Kuhlthau 1989). When applied to high-, middle-, and low-achieving high school seniors, the stages seemed to indicate that information seeking was a complex learning process that involved finding meaning. Aggregate scores from the three groups verified that thoughts move from general to specific to focused during the search process. Thought processes progressed from ambiguity to specificity, and interest increased after the

focus had been formed. It is in the context of this model that student searching behaviors were observed and analyzed.

While the information search was used as the touchstone for determining how well students were prepared for the research process in this study, observation and other data spanned the entire scope of Kuhlthau's model. A qualitative mode was chosen in order to look rigorously at this experience in its natural context and to describe it in detail. For this reason the study was conducted on a limited sample. The intent was to work with two groups of students and generalize to existing or new theories of searching behavior, rather than generalizing from sample to population. The researcher's intent was to treat each of the ten students as a case study to track his/her progress through the research process. Consequently, conclusions are limited to the sample and the study should be replicated to verify findings and for generalizability. This article will focus on the data culled from studying the searching behavior of concept and nonconcept mappers.

Theoretical Framework

Ausubel (1963) noted a distinction between two types of learning: receptive and discovery. Classroom learning has been traditionally dominated by receptive, or rote, learning whereby what is to be learned is presented to, rather than discovered by, the learner. While he conceded that both types of learning can be meaningful—i.e., related to the learner's existing structure of knowledge—Ausubel noted the dominance of receptive learning in the classroom. "As a result, not only have advances in the efficient programming of verbal classroom learning been impeded, but teachers have also been encouraged to perceive meaningful verbal materials as rote in character" (1). While progressive educational practice has mitigated "teach and test" and "teach to the test" syndromes, rote learning is surfacing again as a viable teaching model. Competency testing by state departments of education tends to test content, rather than skills and the application of knowledge. On the other hand, the school library setting is a discovery-learning situation where students interact with information as independent learners. In both classroom and library, students struggle to relate new information to what they already know to make it meaningful. Assimilation theory (Ausubel 1963) has served as the conceptual framework for the development of heuristic devices, such as concept mapping and advance organizers.

Concept Mapping: A Review of the Literature

The heuristic device of concept mapping has emerged as a well-tested and viable tool for promoting concept development. In modifications of Piagetian clinical interviews (Pines et al. 1978), "concept mapping" (Cardemone 1975; Moreira 1979; Stewart, VanKirk, and Rowell 1979; Rowell 1978; Novak 1981) was developed to assess the framework of concepts or propositions that an individual possesses (Novak, Gowin, and Johansen 1983). Novak, Gowin, and Johansen (1983) constructed maps from evidence provided by learners, adding labels to the lines, or linkages, to indicate different "linkage meanings" between the same two concepts. The hierarchical nature of the maps revealed the multi-dimensionality of cognitive structures and scoring keys were developed to evaluate the maps themselves.

The first pedagogical use of concept maps was to help students learn subject matter meaningfully in the areas of mathematics and science at the college level. The first comprehensive study

utilizing concept maps was conducted with junior high school students, who outperformed by a wide margin members of the control group on a test of novel problem solving (Novak, Gowin, and Johansen 1983). In another study mean scores on a problem-solving test in high school physics were two to three standard deviations higher for students preparing concept maps when compared with students who followed a traditional physics program (Novak 1990). Willerman and MacHarg (1991) found that a concept map used as an advance organizer resulted in a positive significant difference in the science achievement of eighth-grade students. Esiobu and Soyibo (1995) verified the efficacy of concept mapping under cooperative, cooperative-competitive, and individualistic whole-class learning conditions in improving student achievement in ecology and genetics.

Using quantitative measures to evaluate concept maps, Austin and Shore (1995) found concept maps were useful in assessing the understanding of relationships between the concepts required for multiple-step problem solving in physics. Trygestad (1997) used qualitative inspection, as well as quantitative measures, of students' maps to generate data of misconceptions and growth in student understanding. Enger (1998) qualitatively analyzed a set of 22 seventh-grade maps and found changes in knowledge representations (reorganization in pre-maps and post-maps, changes in vocabulary usage, the nature of new knowledge representations, and the presence of misperceptions. Enger's study also noted statistically significant differences in pooled pre-instruction and post-instruction concept maps, but not in a class set of pre- and post-instruction maps. Rice (1998) reported that a year-long study implemented in seventh grade life science classes indicated that concept mapping is useful in assessing declarative and procedural knowledge. Markow (1998) found no significant differences between control (essay-writing) and treatment (concept-map-constructing) groups on post-lab multiple-choice achievement tests for first-year, nonmajor college chemistry students (n=32), while interviews with students indicated positive attitudes toward concept mapping. Gold (1998) tested concept mapping in teaching complex notions in urban geography and found that concept mapping techniques increased students' understanding.

The Research Design

This study was conducted in a naturalistic setting that included instruction in the classroom and a research project in the library to investigate the effect of an instructional approach. The study school was an American private school located in a major European city. The student population, composed of 49 nationalities, numbered 1,208. Seventy-four percent of students were American. The faculty was 80% American and almost 20% British. The college preparatory curriculum was typical of American schools. The study took place in a well-equipped middle/high school library/media center with two full-time librarians.

A stratified random sample of ten college-bound students was drawn from two tenth-grade biology classes. Both groups were given a checklist and asked to indicate which biology curriculum concepts were familiar. The list was presented at the beginning of the year to establish that the groups started with similar knowledge, and at the end of the year to ensure that the instruction of both groups covered the curriculum. The researcher also compiled user profiles for each participant in the study. The profiles included gender, ethnicity, facility with English, reading levels as recorded on student records from the standardized tests, biology grades from the last grade reports, and the students' ratings of their familiarity with online searching on a

scale of 1 to 5. Teacher input was used to interpret student records and to compile this data. The results, shown in table 2, guided the selection of participants.

Table 2. Characteristics of the Key Informants

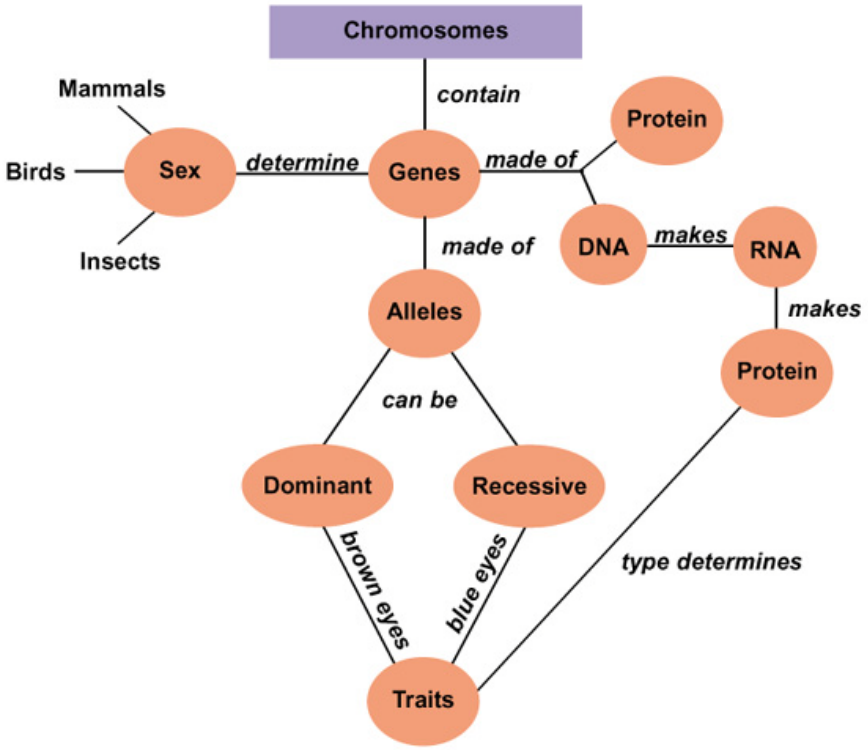
Informant	Voc Cklist (previous)	Bio Test	BioGrade	Iowa scores	Sex	Age	BirthPl	1stLang	Comput Exper
CM									
A	80	86	B	86	F	14	Austria	English	3
B	80	93	B	98	F	15	USA	Dutch	3.5
C	90	89	B	99	F	14	Philip.	English	4
D	60	NA	C+	90	M	15	USA	English	2
E	80	82	B-	81	F	15	England	English	2.5
CM Mean	78	87.5	B-	90.8		15			3
NCM									
F	100	100	A	99	M	15	USA	English	5
G	85	93	C	80	M	14	Holland	English	4
H	70	100	B	84	M	15	Canada	English	3
I	80	90	A-	99	F	16	India	Hindu	4
J	55	NA	B-	96	M	14	USA	English	3
NCM Mean	78	95.8	B	91.6		15			3.8

The use of concept mapping may have had the Hawthorne effect—that is, the experimental group was more able or motivated or was doing more. Sample selection measures, in addition to teacher-made tests administered throughout the unit, minimized this effect.

An important factor in selection was the willingness of students to participate as key informants in the study. The sample was thus drawn from a pool of volunteers. The sample was not intended to be representative of the school in which the study took place. Five students were chosen as key informants from the class that was taught concept mapping and they served as the experimental group. Five students were chosen from a class that received the same instruction, research assignment, and library instruction without concept mapping. This small sample made an in-depth analysis of qualitative data possible. The study encompassed the entire research process from topic selection through writing the paper, with the focus on the information search.

The two study groups were taught by the same teacher to control for differences in teacher effectiveness and method. The biology teacher taught one class in the conventional manner, covering all curriculum topics, including an introduction to genetics, as illustrated in figure 1.

Figure 1. Teacher's Concept Map of the Genetics Unit



Teaching methods used by the biology teacher included class discussion, demonstration, hands-on activities, small group work, science labs, and limited lecture. Instructional aids included a textbook, (*Biological Science: A Molecular Approach*, BSCS Blue version, 6th ed., D.C. Heath and Co.), audiovisual materials, and computer-assisted instruction using interactive software. The software, Biology Explorer: Genetics, was used to reinforce the concept of monohybrid inheritance (i.e., pure lines; dominant and recessive alleles; phenotype and genotype; homozygote and heterozygote; Mendel's First Law) and the monohybrid test cross. The teacher also used the program to elaborate on, and give more examples of, the elementary laws of probability using large sample sizes. "Basically," she noted, "rather than drilling them with repeated genetics problems, they ran models and used questions from me on paper to guide their learning."

The other class received the same instruction. In addition, this group was taught to use concept mapping continuously and consistently during the year as detailed in Novak's book, *Learn to Learn*, which was used as a guide by the teacher. Since the experimental group was asked to do something extra, it may be conjectured that the mappers spent more time learning concepts or thinking about searching. To minimize this perception, search strategy was taught by the librarian to both groups as part of the research unit and included the mechanics of searching. The groups also received the same instruction regarding vocabulary and concepts within the biology unit of study. The same amount of time was spent on the topics and concepts in each unit. The

benefit of concept mapping accrues to the person who designs the map and building skills in mapping takes place over several months time (Novak, Gowin, and Johansen 1983). For these reasons, contact between members of the two groups would not have compromised the effects of concept mapping on searching behaviors.

The librarian taught a library unit that included an introductory lesson to the reference tools and electronic searching. Students were required to write a proposal subsequent to three days of sustained silent reading in the library that precluded note taking. This method was intended to promote focus formulation. The information search in the library immediately followed, lasting about three weeks. The biology teacher and librarian collaborated with the researcher to design a conventional research assignment culminating in a written paper. Students chose topics from a teacher-made list, which included topics such as using monoclonal antibodies to immunize humans, the use of DNA testing in police work, the benefits and disadvantages of transgenic animals, and cloning. Basic concepts underlying these topics were taught to both groups, but students were expected to expand their knowledge of the topic through research.

The librarian instructed classes in the use of library sources of information, including print indexes to *New Scientist* and *Critical Issues*, the *Readers' Guide to Periodical Literature*, and the use of automated search systems, including a computerized OPAC and the *Social Issues Resource Series* (SIRS) in electronic format. These library reference tools were used because they are common to most school libraries and were accessible to all students. The period of data collection on students' searching behavior was two weeks, but data collection extended from topic initiation through writing the paper. Table 3 provides a summary of data collection methods. Data on searching were collected from three to five think-aloud sessions for each key informant. These sessions were audio recorded by the researcher as students searched for information. Informants wrote transaction logs from memory immediately following each search. These sessions were followed by structured interviews. Stimulated recall was used as an interview method; key informants were provided with written transcriptions of their think-aloud sessions, which were discussed in interviews. These methods were replicated with the biology teacher and librarian serving as "experts" to compare their searching with student searching. Students, the teacher, and librarian maintained journals from the beginning of the genetics unit to the end of the research project to document their thoughts, feelings, and observations. Debriefing took place immediately following each session of data collection.

Table 3. Summary of Data Collection

I. The Classroom Unit

A. Control Group

1. Teacher-made pre-test on vocabulary and concepts administered.
2. Traditional lessons taught.
3. Two teacher-made tests of student knowledge administered.
4. Student key informants selected using data from user profiles.

B. Experimental Group

1. Teacher-made pre-test on vocabulary and concepts administered.

2. Studies on concept mapping given to teacher.
3. Teacher trained in concept mapping using *Learning How to Learn*.
4. Lesson plans that incorporate concept mapping methods generated by teacher.
5. Students received hand-outs, introduction to concept mapping.
6. Students taught characteristics of maps using good and bad examples. Students receive directions on concept mapping; made individual maps.
7. Students given feedback from the teacher for at least 3 sub-topics of the unit including scoring using Novak and Gowin's (1984) comprehensive scoring scheme.
8. Two teacher-made test of student knowledge administered.
9. Expert concept maps made by the teacher for at least 3 unit sub- topics.
10. Student key informants selected using data from user profiles.

II. The Library Unit

A. Control and Experimental Groups

1. Teacher and librarian collaborated to design the research unit and packet of support materials for students.
2. Students chose topics from teacher-made list.
3. Librarian gave instruction in use of packet (Glossary, Note-taking Sheets, Bibliography Charts), sources of information, and using automated search systems.
4. Teacher/Librarian graded research paper and research process (packet) respectively.
5. Librarian conducted three expert searches.

III. Methods of Data Collection from Key Informants

A. Think-alouds

1. Think-alouds conducted for each key informant (minimum of three per student, two per teacher, two per librarian).
2. Each session audio-taped and transcribed.

B. Interviews

1. Individual interviews conducted for students, teacher and librarian for a minimum of three times at staggered intervals during the search process for a minimum of ten minutes each.
2. Stimulated recall using transcriptions of think-alouds during sessions incorporated with interviews.
3. Each session is audio-taped and transcribed.

C. Journals

1. Students kept journals detailing their thoughts and feelings throughout the research process as well as their searching strategies.
2. Students made transaction logs from memory immediately after each search.
3. Teacher and librarian kept journals of their observations of students.

4. Teacher and librarian made transaction logs from memory after each the observed expert" "searches they per formed, including time lines, time logs and flow charts.

D. Debriefing

1. Debriefing occurred following each data collection session for all key informants.

Data Analysis

The data were analyzed both qualitatively and quantitatively. The former analysis used the constant comparative method and grounded theorizing to find trends and patterns in verbal data (Glaser and Strauss 1967). While searching behavior is the focus of this article, the study included data drawn from each stage of the research process and is presented as supporting or contradictory evidence, as the case may be, for the quantitative data established by a formula based on probablility and Bayesian statistics. Qualitative data was triangulated with quantifiable data generated by information searches using a mathematical formula based on information theory proposed by Fano (1961) and developed in the field of Bayesian statistics.

Information theory, which has been used in the development of artificial intelligence systems and the construction of knowledge bases, is a viable alternative to classical statistics. Used in decision theory, it seems especially appropriate for researching the information search in which dichotomous situations constantly confront the searcher. Information theory has developed in directions that are of interest as statistical measures and as quantifiable concepts in library science (Parsaye and Chignell 1988). Generally, information theory is not concerned with confidence levels but with the amount of information in favor of an event happening. The amount of information is a kind of degree of confidence. Rather than rejecting a hypothesis, or in the case of qualitative research, a theory or proposition leading to theory formulation, a certain threshold related to the value of the information can be used to make a decision.

The kind of information that most closely relates to perceived meaning or new knowledge can be represented by the statement

> Information now learned about A = what you now know about A - what you knew or expected about A.

Related to this statement is the Fano measure, a measure of mutual information that can be described as measuring the information relating A to X. Fano's measure embodies these concepts of expected information, expressed in logarithms:

> I(A;X)=log [(number of times A and X are observed together
> (number of times A is observed, i.e., with or without X)]

Interpreted in terms of one of the measures of this study, this formula reads:

> The information that X (concept mapping) provides about searching behavior (A) is equal to the log of the number of times A and X are observed together divided by the number of times A is observed, with or without X (concept mapping).

In broader terms, the concept can be stated as:

> Information learned about A = What you now know about A - What you knew or expected about A.

Bayesian statistics refined the formula as follows:

> I(use=print : electronic ; concept mappers) =
> log[P(concept mappers, print) / P(concept mappers, electronic)] - log[P(print) / P(electronic)]

which is read as:

> the amount of information (I) provided by (indicated by a semi-colon) concept mappers that the student will use print at any time as opposed to (indicated by a colon) electronic means is equal to the log of concept mappers in print divided by concept mappers in electronic minus everyone searching in print over everyone in electronic (which represents the expected probability that the searching behavior would occur anyway, or by chance).

Mathematical probability is based on a model that assesses the frequencies of sequences of events. The formula based on Bayesian statistics addresses expected probablility: the probability of A occurring by chance, which is the same principle used in standard statistics. However, the chance situation is not always the most useful or meaningful basis. For example, there is more hope of finding *Oliver Twist* in a library than in an average room in an average house (Parsaye and Chignell 1988). It is possible to introduce a kind of probability that is pragmatic so that one will make a decision that is more profitable or less risky. For example, the decision to look for a book in a library rather than in an average room might be reassessed if entering a library cost a lot of money. A condition can be introduced into the formula so that we can state there is more hope of finding *Oliver Twist* in a library than in an average room in an average house conditional upon free access to a library.

The Bayesian approach to probability relies on the concept that one should incorporate the prior possibility of an event into the interpretation of a situation (Parsaye and Chignell 1988). Bayes's equation is a special application of conditional probability.

The information measure resulting from applying this formula can be positive (A has more chance than you would expect), zero (the occurrence of A is just what you would expect and there is no information), or negative (A has less chance than you would expect.) The units of measure depend on the logarithms used:

> Base 2 - binary units or BITS
> Base 10 - decimal units or HARTLEYS
> Natural logs (base e) - natural units or NATS

NATS is recommended for statistics: the natural logarithm is usually the automatic setting on a calculator.

The following points of grammar translate the formula from its mathematical language to colloquial speech:

I = information
Semi-colon = provided by
Colon = as opposed to
| = conditional upon

Unlike classical statistics, information measures speak of results that are "meaningful" rather than "significant." Significance levels, traditionally set at .05 and .01 to determine the probability of the outcome occurring by chance, are replaced by a measure of one nat, which is considered "meaningful."

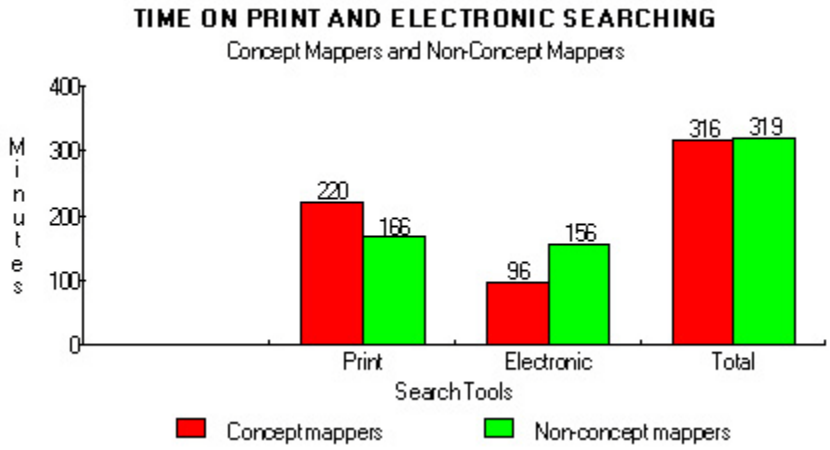
The researcher identified ten searching behaviors as points of analysis to determine if there was a meaningful difference between the searching behaviors of concept and nonconcept mappers: (1) preference for print vs. electronic formats; (2) preference for SIRS vs. OPAC; (3) preference for subject heading vs. keyword searching; (4) total number of search words in searching repertoire; (5) number of unique search words; (6) incidence of opening moves; (7) the number of reformulations; (8) the number of search operations; (9) the incidence of breadth searching; and (10) the incidence of depth searching.

Findings

Print versus Electronic Searching

Will concept mappers be inclined to use print or electronic resources? Figure 2 illustrates that although the total searching time of both groups was virtually the same, concept mappers spent 96 minutes in electronic indexes while nonconcept mappers spent 156 minutes.

Figure 2. Total Time Spent Searching on Print and Electronic Search Tools



Another way of highlighting the differences in apportionment of time is shown as percentages in figures 3 and 4.

Figure 3. Search Time Allotment—Concept Mappers

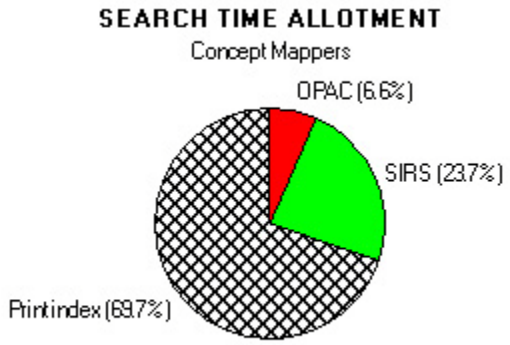
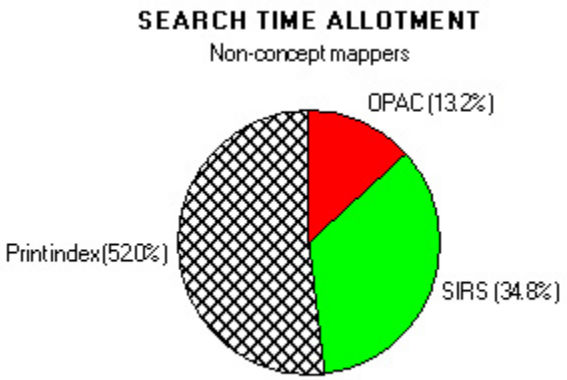


Figure 4. Search Time Allotment—Non-Concept Mappers



A useful way of encapsulating the essence of these diagrams and avoiding the subjectivity inherent in visual judgment of, for example, the relative heights of bars in a histogram, is to process the quantities represented to information measures (Markow 1998). To allow this analysis, the amount of time spent in each kind of pursuit (use of print, use of electronic) is interpreted as proportional to a probability, that is, the probability that the student will be found in the specified pursuit, such as use of print, at any time. The formula used is as follows:

> I(use=print : electronic ; concept mappers) =
> log[P(concept mappers, print) / P(concept mappers, electronic)] - log[P(print) / P(electronic)]

Substituting the times as shown in figure 2, we obtain log[220/96] - log[386/252] = +0.40 nats as the measure of that information. The results can be expressed as

I(use=print : electronic ; concept mappers | time spent) = + 0.40 nats

which could be read as, “the amount of information provided by concept mappers conditional on time spent that the student will use print as opposed to electronic means measures +0.40 nats. The positive result indicates that the information is information in favor of the student using print means at any time. Repeating this but using information supplied by nonconcept mappers, we obtain the information measure:

I(use=print : electronic ; nonconcept mappers | time spent)

Or, substituting values from figure 2:

I(use=print : electronic ; nonconcept mappers | time spent)
= - 0.36 nats

which could be read as "the amount of information provided by nonconcept mappers *conditional on time spent* that the student will use print as opposed to electronic means measures at any time as opposed to electronic means measures -0.36 nats.” This measure, being negative, indicates that the information is information against the nonconcept mappers using print at any time. As it happens, the effect is quite strong, such that this can be taken as equivalent to the concept mappers’ propensity to print. However the subtlety of the measure is that it could be that the concept map training was shown to have a positive effect even if it was still less probable that print would be used. For example, your vote is a step in the right direction for your party even if it doesn’t get elected!

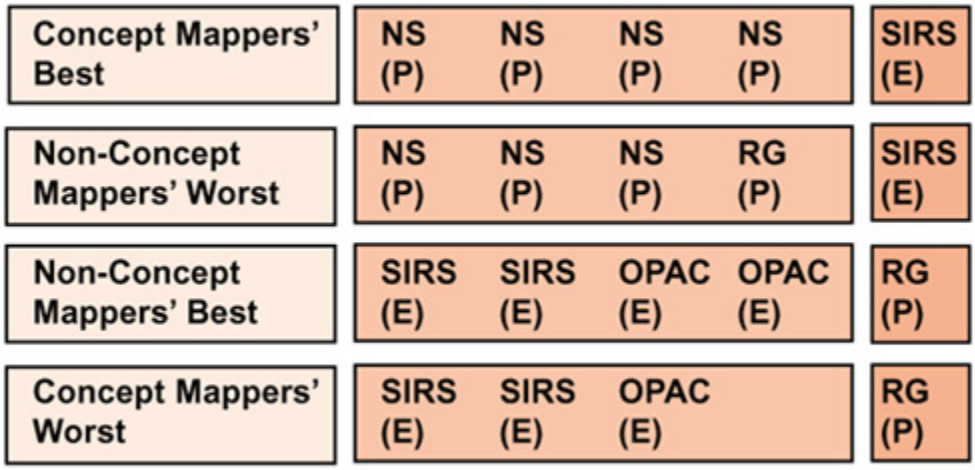
The difference between measures for mappers and nonmappers is +.767. That is approximately three-fourths the value of 1 nat (1 = natural log 2.718), or 2.04. This means that if there was the expectation that no bias existed between the use of print as opposed to electronic by mappers and nonmappers regarding time spent, the difference between the time spent by mappers and nonmappers in print is more than 2 nats. A measure of 1 nat or more is generally regarded as particularly “meaningful.”

Qualitative data provided evidence for formulating hypotheses that could explain the effects indicated by application of the Fano-based measures. When asked whether they preferred print or computer searching, concept mappers did not share a consensus as a group. It was not yet obvious why concept mappers allocated more time to print.

Nonconcept mappers unanimously expressed a preference for electronic rather than print, because computers seemed to make searching easier. Their reasons for the preference indicated that either the computer helped them to cut through large quantities of information or it provided them with a lot of information, which made them feel confident about searching even if that information was irrelevant.

The researcher triangulated data on stated preferences with the judgments searchers made about their best and worst searches, which are shown in figure 5. Print searches were chosen for the concept mappers best searches and for the nonconcept mappers worst four out of five times. Similarly, computer search tools were chosen as nonconcept mappers’ best and computer tools were chosen as concept mappers’ worst in almost the same ratio.

Figure 5. Searchers' Best and Worst Searches



Scrutiny of the search tools offered some clues for preferences. From the four concept mappers who preferred print indexes, three stated the *New Scientist* as their preference, which was the most difficult search tool to use because of its complicated coding system. It also indexed the most difficult, yet scientific and technical, reading material. The fourth concept mapper who preferred the print index stated a preference for *Critical Issues*, which indexes articles from the *New York Times.* This index was also difficult to use because it was coded to microfiche that was retrieved from a binder separate from the index. Searchers also had to learn how to use the microfiche reader printer. Concept mappers did not perceive any of these difficulties as obstacles. Some even saw the print indexes as an aid in focusing: "The *Readers' Guide* has helped me focus by showing me what articles are available on different subjects and to break down the subject." On the other hand, nonconcept mappers chose the same types of indexes as their worst search tools, with the exception of Christian. He noted in his journal that the Readers' Guide "has been my longest search so far. What I achieved through the search . . . is that out of the huge number of sources the search provided, it helped me to realize that a lot of the information that I had been considering was irrelevant given the time and length limits placed on this paper. I think this was the first search which has made me realize that I must maintain my focus if I am ever going to get this done!" The tendency of mappers to spend more time in print indexes was directly related to their perceptions that they yielded: (1) a high quality of scientific, technical information; (2) a large number of sources; and (3) a rich supply of search terms the indexes through cross-references and titles. In this case, print sources were superior to electronic: the library catalog offered books only when more specialized, up-to-date periodicals would be more appropriate for this assignment. SIRS, the other electronic tool, offered the advantages of periodicals and was perceived by both groups to be a helpful tool.

A closer look at what the searchers were doing with their time revealed more information about the reasons for their preferences and time allotments. The number of sessions that the two groups searched differed, as shown in table 3. Concept mappers searched a total of 24 sessions, 7 of which were electronic searches, which represents 29% of their total number of search sessions

compared with the nonconcept mappers, who had 9 electronic search sessions, which represents 53% of their total number of search sessions. For print sessions, the reverse was true with concept mappers spending 17 sessions, or 71% of their total number of sessions, in print; nonconcept mappers spent 8 sessions using print indexes, or 47% of the total number of sessions.

These comparisons support earlier findings that mappers showed a preference for print index searching, allocating more sessions and longer periods of time to them. When the number and length of search sessions is examined (see table 4), it can be seen that concept mappers spent more time and more sessions in print. In sessions that were shorter in duration than nonconcept mappers, were the mappers searching faster and possibly doing more, or searching shorter periods of time during which they were doing less? Why did concept mappers search about one-third of their time on electronic tools while nonconcept mappers searched almost half their time on computers? Why did concept mappers prefer print indexes while nonconcept mappers spent considerably more time on electronic searches? Did electronic methods compensate for nonconcept mappers lack of a conceptual map? Do electronic methods benefit concept mappers or nonconcept mappers? Data were needed that indicated if concept mappers were searching more efficiently in electronic tools and more thoroughly in print indexes than their nonmapper counterparts. Examination of the remaining search characteristics was intended to explore how searchers used their time and the rates at which they performed search functions in order to make judgments about efficiency and thoroughness of their searches.

Table 4. Number and Length of Search Sessions

	Total Time (minutes)	Length of Session (minutes)	Number of Sessions	Mean Time per Searcher
Electronic				
CM	96	19.2	7	2.7
NCM	156	30.6	9	3.7
Print				
CM	220	12.9	17	1.8
NCM	166	20.8	8	2.6
Total				
CM	316	13.2	24	12.9
NCM	319	18.8	17	

SIRS versus OPAC

The information measures for this comparison are as follows:

I(use=SIRS : OPAC ; concept mappers | time spent) =
+ 0.962 nats
I(use = SIRS : OPAC ; nonconcept mappers | time spent) =
- 1.650 nats

These may be read respectively as "the information that the use will be SIRS rather than the OPAC, as provided by concept-map training" and "the information that use will be SIRS rather than the OPAC as provided by nonconcept-map-training." Both are based conditionally upon time spent. The fact that the second is negative supports use of the OPAC rather than SIRS by nonconcept mappers. These information measures are even stronger than the corresponding measures distinguishing print and electronic use. Subtracting the first measure from the second gives a measure of the difference between the two groups:

I(SIRS : OPAC ; concept mappers:nonconcept mappers | time spent) = + 2.612 nats

In this case 1 nat would mean that *if* there was the expectation that there is no bias between use of SIRS and the OPAC, the information obtained would mean that concept mappers spent 2.718 times more in SIRS than in the OPAC (1 = natural log 2.718). The information measure of -1.650 nats for nonconcept mappers using SIRS as opposed to the OPAC is thus particularly "meaningful" and would be the expected measure *if* there was no expected prior bias. The data showed, however, that the nonconcept mappers spent 19% of the time in SIRS as opposed to the OPAC (i.e., less than one-fifth of total searching time).

Data from interviews showed that all concept mappers said they preferred SIRS rather than OPAC "because there was a lot of information there. A lot of books I find older and not up-to-date, whereas in SIRS everything is relatively recent, within the year, so it's better." Nonmappers preferred the OPAC because "it was a little more straight to the point . . . whereas with SIRS you definitely have to go into more in-depth reading about the article to decide if it's going to help you." "It was just easier for me because with SIRS I had to read through every article until I found the words . . . I had to read through a lot of unnecessary stuff." Nonmappers who said they preferred SIRS actually spent more time searching through the OPAC. One student commented that in SIRS "There was a lot of information and it was hard to find what was relevant. I was not overwhelmed but close to overwhelmed. There's too much information." An emerging explanation for nonmappers' preferences for the OPAC, although it was not the best tool for the research, was that nonmappers were more sensitive to information overload. This preliminary conclusion directed the analysis of data culled by observing students at various stages of the research process. Nonconcept mappers spent more time than concept mappers in the prefocus formulation stage and their finished papers reflected that in some cases they never achieved focus while all of their concept mapper counterparts did.

Subject versus Keyword Searching

Information measures indicate that information was in favor of mappers using subject as opposed to keyword searching, as shown in the following:

I(use=subject : keyword ; concept mappers) = + 0.74 nats

Since there are no keyword possibilities in using print, this is consistent with the fact that concept mappers spent more time in print. Mappers exercised the same number of search operations (11) as nonmappers in print (11) but did so in less time. Since the difference is clearly that nonconcept mappers executed far more keyword searches (35), the preliminary inference is that nonconcept mappers used keyword searches less efficiently than concept mappers. This is consistent with the fact that electronic searching (which allows keyword use) by concept-mappers proceeds at a higher speed than print searching.

The information measure is information against nonconcept mappers using subject as opposed to keyword searching:

I(use=subject : keyword ; nonconcept mappers) = - 0.41 nats

The raw data in table 5 shows that nonconcept mappers executed more than 3 times as many keyword as subject searches. Comments from interviews confirmed the trends indicated in the raw data and information measures: four of the five nonconcept mappers said they preferred keyword searching. “You can narrow it down more and you can look through all the articles because keywords are highlighted.” A concept-mapper elaborated on this, stating, “[keyword] gives you more specific information . . . [and] tends to weed out any information which I really don’t need.” The fifth nonmapper preferred subject searching because "It’s more direct. You can get anything as long as the word is in there.” Her objection to keyword was that it could give you irrelevant information. The consensus of nonmappers, similar to their reasons for preferring OPAC to SIRS or electronic searching to print, was that they perceived their preferences helped them to manage information. A typical comment was “It seemed there was a lot of information, that it was going to be hard finding what I needed and sorting out from the information I didn’t need and finding the right terms and learning what they meant . . . It was a lot of work . . . to get some background so I could focus on the fine point that I wanted. It was hard to find what was relevant and what was not, what I would actually be using, which information I might throw away and what I needed to come back to later.” Were emerging issues of relevance and focus functions of lack of prior knowledge and weak concept formation?

Table 5. Subject Heading and Key Word Searches

	Number of Concept Mappers’ Searches	Number of Non-Concept Mappers’ Searches
Subject		
SIRS	6	5
OPAC	5	6
Total	11	11
Key Word		
SIRS	7	18
OPAC	4	17

Total	11	35

Search Word Repertoire

Repertoire of search words was used as a measure of focus and was computed by extracting search words from each recorded search. Unique search words were words that were counted only once, whether they reappeared as a single word or as part of a term. For example, “monoclonal” was counted as a unique search word whether it appeared as the word “monoclonal” or in the term “monoclonal antibodies”; “antibodies” was counted once whether it appeared as the word “antibodies” or in the term "monoclonal antibodies.” The search repertoire of nonconcept mappers was larger than that of concept mappers, with 52 unique search words compared with 21 for concept mappers. This difference is emphasized in an information theory approach using the measures that are derived, not from interpretation of probability as proportional to time, but proportional to the number of nonrepetitive words. The information measures obtained are as shown below:

> I(use=print : electronic ; concept mappers | non-repetitive words) = + 0.61 nats
> I(use=print : electronic ; nonconcept mappers | non-repetitive words) = - 0.41 nats

Unique words appear to relate to less information because second and subsequent uses of the same word are not redundant; in information theory parlance, they do not carry “degenerate information.” Subsequent use of the same word is in a different context and for a different purpose at a different stage, even (typically) in a different search tool within the category. The measure

> I(use=print : electronic ; concept mappers : nonconcept mappers | search words) = + 1.65 nats

—which is simply the difference between the two measures—means that the concept mappers have a 1.65 nats advantage over nonconcept mappers. The corresponding measure for nonrepetitive words only is 1.02 nats. This indicates that concept mappers have less advantage with regard to the use of nonrepetitive, or unique, search terms. The difference between the two groups is still meaningful—greater than than 1 nat. Mappers used a smaller repertoire of search terms than nonmappers. Think-aloud sessions revealed a higher level of satisfaction upon terminating the search among mappers; nonmappers consistently applied more search terms because, by their admission in think-alouds, they were not finding relevant information.

When asked, searchers almost always said they did not have a strategy. One searcher did have strategies but could not articulate them. “It’s hard to identify a pattern,” observed a nonconcept mapper, ”because I was learning so much new information . . . I would jump round and find new information and that would lead to more information.” Comments about how they started their searching, however, did reveal a strategy that was common to both groups. A mapper commented, “I think I always started on the broad side.” A nonmapper concluded, “I was using general terms at first.”

Implicit in all judgments about strategy is the underlying question of what constitutes a good search. Examining whether searchers thought their searches were successful helped to define their expectations and the implicit strategy they used to realize them. The dichotomy between finding information and finding search terms was evident. Concept mappers quickly shifted from the former to the latter. In her first interview, Ann said she thought a search was successful "If I find a few articles that are going to be good, that could be useful." During her third searching session, Ann made the shift. "I found one article . . . this seems interesting to me because not only might it help me with heredity or genetics, it might shine a light on a new topic or keyword that I can look up to help me with my topic." The other concept mappers expressed a similar progression: their information search narrowed from "anything on my topic" to gathering keywords that represented key concepts. The progression to specificity was accompanied by a reflective evaluation of their knowledge state that led to a focus on what needed to be known.

Three nonconcept mappers saw keywords as critical to successful searching but did not see themselves as successful in using keywords. "If I had been able to do a more specific keyword search, I am sure I would have found even more information." "I felt angry when I ran out of ideas to use in keyword search. If I could do it again, I would think of more words to use in keyword search." The other two did not exhibit the same metacognitive insights. For example, Peter's criterion remained the same throughout his searching: he wanted to find information. At no time did Robert collect search terms, although it was obvious by the increasing specificity of his search word repertoire that he was accumulating scientific language.

Opening Moves

Opening moves were defined as search words used to begin a string of search moves. A succession of strings made up a search session. The number of opening moves, was, in effect, the equivalent of the number of strings or successive search moves that led eventually to one or more hits, a dead-end, or cross-references.

The information measures for the total number of opening moves are:

I(use=print : electronic ; concept mappers | openings) = + 0.72 nats
I(use=print: electronic ; nonconcept mappers | openings) = - 0.56 nats

These measures indicate that mappers were more likely to change their searching by initiating opening moves. When time is factored into the measure, however, it is clear that mappers were generating opening moves at the faster rate of 4.4 opening moves per minutes compared with the nonmappers' rate of 2.8 per minute in electronic searching. The mappers' faster generation of opening moves and, consequently, greater number of search strings indicated that they were generating more initiatives and sustaining their searches in a string, thus requiring fewer opening moves. The information measures

I(use=print:electronic : concept mappers | openings per minute) = - 0.25 nats/min
I(use=print : electronic ; nonconcept mappers | openings per minute) = + 0.30 nats/min

emphasize that concept mappers generated fewer opening moves in print than in electronic searching while the opposite is true for nonconcept mappers. We can interpret this as concept mappers processing +0.25 nats/min. in electronic searches as opposed to print searches, and

nonconcept mappers +0.30 nats/min. in print as opposed to electronic. The extra information being processed by concept mappers in electronic searching (relative to print) as opposed to nonconcept mappers is -([-0.25]-[+30]) = 0.55 nats/min.

If search termination is defined as the point at which the searcher declines to make an opening move, reasons for search closure may hold explanations regarding opening moves. When the question "When do you consider that your search is over?" was asked, the two groups showed no difference in their responses. The most prevalent answers included "When I can't think of any search terms" and "When I have enough information." When think-aloud transcripts were examined, the question proved to be time sensitive. Mappers terminated their first four searches because they had exhausted their sources and ended their last three searches because they wanted to read. Nonmappers terminated their earlier searches because they were out of search terms and ended the later ones because they had enough information.

The question of search termination was sensitive to the sources that were used at the time. Nonmappers ran out of search terms more often when they were searching electronically. Since they were spending a longer time than mappers searching in the electronic tools and had a larger repertoire of search words, we can conclude that these electronic searches were not more efficient. In fact, nonmappers were using electronic searching in a less efficient manner, perhaps to compensate for their lack of focus or their need to conceptualize more clearly about the topic. It is also interesting that concept mappers, who spent more time searching in print, ended their searches more frequently because they felt they had exhausted the sources or had enough information from them.

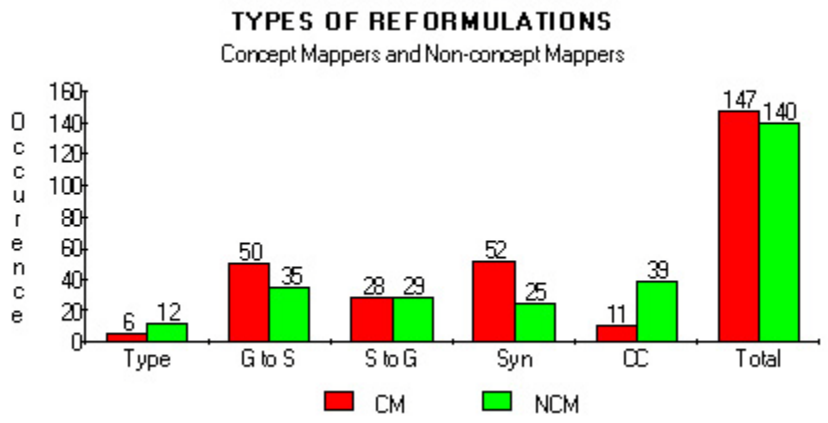
Failure to make an opening move, synonymous with search closure, could be said to occur for the same reasons. The fact that nonmappers generated opening moves in their electronic searching at a rate that was almost half that of mappers suggests they were not as efficient as mappers. Mappers never terminated a search because they ran out of search terms, indicating that they were thorough in their electronic searching and successful in retrieving relevant information.

Reformulation

The total number of reformulations—changes in search words within a search string—was not dissimilar between the two groups: mappers performed 147, with a mean of 29.4, while nonmappers performed a total of 140, with a mean of 28 (see figure 6). When the information in favor of mappers and nonmappers reformulating in electronic searching were calculated, the results were as follows:

I(use=print : electronic ; concept mappers | re-formulations) =
+ 0.78 nats
I(use=print : electronic ; nonconcept mappers | re-formulations) = - 0.57 nats

Figure 6. Types of Reformulations



When total reformulations were calculated per minute, it was found that concept mappers reformulated in print indexes an average of 1.7 times per minute and nonconcept mappers averaged a rate of 1.8. In electronic searching, however, concept mappers reformulated an average of 5.3 times per minute and nonmappers averaged 3.1. Concept mappers were performing fewer reformulations, but they were reformulating at a faster rate.

The information measures are interestingly inverted in sign when this is applied to the rate of reformulation. The following measures based on rate emphasize the higher rate of reformulations per minute in electronic mode relative to print mode by nonmappers:

> I(use=print : electronic ; concept mappers | re-formulations per min) = - 0.26 nats/min
> I(use=print : electronic ; nonconcept mappers | re-formulations per min) = + 0.34 nats/min

It may be recalled that I(use=print:electronic. . .) is the same value as I(use=electronic:print. . .) but reversed in sign. In other words, mappers as opposed to nonmappers have a higher rate of re-formulations per minute in electronic use relative to print than we would expect, and yet they spend a longer time in print.

Reformulations could be categorized as occurring for the following reasons: (1) change of search type (Type), that is, switching from subject, author or title, or from subject heading to keyword; (2) change from a specific to general search term (S to G); (3) change from a general to specific search term (G to S); (4) use of a synonymous word or term (SYN); and (5) change of concepts (CC). When the informants' reformulations were broken down into these categories, the results indicate that the greatest difference between the two groups was in their change of concepts. Mappers shifted 11 times and nonmappers shifted 39 times. The second largest difference was the use of synonyms, with concept mappers reformulating with synonymous words 52 times and nonconcept mappers using synonyms 25 times. The category of general to specific presented the third largest difference, with mappers reformulating to more specific terms 50 times and nonmappers doing so 35 times. This evidence supports the conclusion that concept mappers progressed toward a greater degree of specificity in their search terms. Mappers seemed to shift their types of searches less frequently. In light of the fact that nonmappers used many more

keywords (35) than mappers (11) it can be said that they probably spent more time trying to reach a degree of specificity that worked well. Mappers were more consistent in the types of searches they conducted, evidenced by the fact that they only changed types 6 times while their counterparts shifted search types 12 times. The significance of the reformulation rates cannot be categorically declared by this quantified analysis. Dialogue documented in think-alouds, however, revealed that nonmappers reformulated for two reasons: (1) they did not find any information; and (2) they did not recognize the relevance of the information they found.

Search Operations

Search operations referred to the conduct of subject heading and keyword searches in both print and electronic indexes that resulted in any number of hits, including zero hits. In fact, they were a measure of a particular type of reformulation— changing the type of search. Search operations differ from the distinction between subject heading and keyword searches in that they include both print and electronic searching. Obviously in electronic searching the searcher has the option to choose subject heading or keyword searching; in print all searches are considered subject-heading searches. Search operations begin with opening moves and may include reformulations. For example, the search term ”monoclonal antibodies” could be applied as a keyword search as an opening move and may be changed to “monoclonal” as a reformulation. An operation was terminated when no other search term was generated by that search.

Search operations for concept mappers exceeded those for nonconcept mappers in print searching. Mappers logged 149 operations and nonmappers logged 91. In electronic searching, mappers spent less time doing more, and their search word repertoire was more concise.

The information measures

I(use=print : electronic ; concept mappers | searches) = + 0.79 nats
I(use=print : electronic ; nonconcept mappers | searches) = - 0.64 nats

emphasize that more searching was done in print by concept mappers. Addressing search operations per minute, we obtain

I(use=print : electronic ; concept mappers | searches per minute) = - 0.33 nats/min.
I(use=print:electronic ; nonconcept mappers | searches per minute) = + 0.38 nats/min.

It is to be recalled that I(use=print : electronic . . .) is the same value and of opposite sign to I(use=electronic : print . . .). This emphasizes that the concept mappers had a higher rate of total electronic operations relative to print operations and that mappers had a higher rate of total print operations relative to electronic operations.

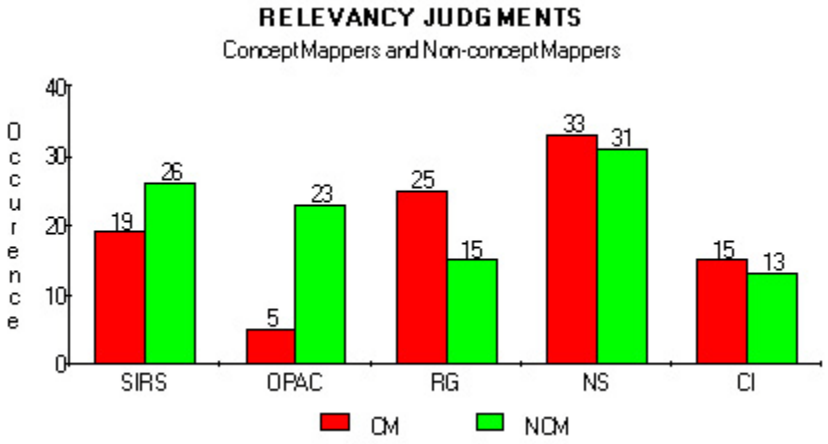
Relevancy Judgements

Inherent in every search operation was the decision of relevance. Data from this category, qualitatively analyzed, provided information about what the searchers were doing when they were performing these search operations. A positive or negative judgment has an impact on the conduct of the search, because that judgments determines the “success” of the search in the mind of the searcher (based on the premise that most searchers most of the time look for information).

Relevancy judgments regarding the titles of sources retrieved electronically and from print were tracked during think-alouds. Searchers were asked why they rejected or accepted titles, but the statistics only included as many judgments as were verbalized, which we can assume were judgments that the searchers saw as important decisions. It was not possible for them to verbalize every judgment of relevancy, but all relevancy judgments that were positive were verbalized as the searcher recorded the title or citation. It can be assumed, therefore, that the number of titles deemed relevant (R) are inclusive, whereas the number of titles deemed not relevant (NR) represent a minimal, or partial, number of those items actually rejected. For this reason information measures could not be calculated for relevancy judgments (the exact number of nonrelevant items being unknown) and the analysis concentrates on the number of items chosen as relevant.

Figure 7 illustrates the number of relevant choices for each of the search tools for the two groups. The most striking difference is in the OPAC, where mappers only made five positive choices while the nonmappers made 23. This could be a function, in part, of the time allocation to electronic sources by the nonmappers. It is also interesting that the mappers did not consider the OPAC the best source of information. In SIRS, the other electronic source, nonmappers chose 26 titles compared with the mappers' total of 19, continuing the trend of choosing more items that were perceived to be relevant in electronic tools. The mappers, on the other hand, found more relevant items in print indexes, where they spent more time, and where they said they had their best searches.

Figure 7. Relevancy Judgments



The question of relevance was sensitive to the timing in the search process, especially regarding the degree of focus the searcher had achieved. At the beginning of the project, replies were aimed at gaining knowledge of the subject, but there was lack of specificity.

As focus developed, definitions of relevance became more utility based: "I decided whether I could use them in my paper . . . if there were facts; if they mentioned the actual technique . . . some articles had a list of benefits, exact, precise, very specific benefits." When students achieved focus and knew the genetic terminology for their research, their criteria for selection

became more specific. “What makes an article good? It’s humans and antibodies and vaccines, and it’s medical.”

Choice of articles supported what searchers said about their criteria for selection. Titles that were more specific, technical, and “scientific” were chosen more frequently in the later searches than in the earlier ones. Concept mappers made more relevancy judgments in print sources, where the more technical and scientific reading materials were retrieved, than nonmappers. This may be because of their sharper focus on the topic, which allowed them to execute searches and retrievals that displayed a higher degree of specificity. The largest difference between the numbers of relevancy judgments in the two groups was in the OPAC, which by nature of its cataloging and content, offered the less specificity than periodical indexes. It was clear to mappers that periodicals offered up-to-date, research-oriented information. Nonmappers persistence in time and effort spent in the OPAC searching environment indicates that they continued to make relevancy judgments beyond what was productive.

Students who had trouble focusing did not achieve a high degree of specificity and tended to focus on ethical and moral rather than scientific aspects of the research topic. There was more concern with these digressions among nonmappers. Given the academic equivalency of the two groups, the tendency of nonmappers to avoid the hard science was probably related to their struggle to focus the topic and feel comfortable with the terminology.

Breadth and Depth Searching

Another revealing search characteristic was breadth and depth, which indicated how many times the searcher moved laterally (using more opening moves) and vertically (sustaining a search string and reformulating within it). The breadth and depth of searches were calculated by counting the number of lateral moves, which is equivalent to the number of opening moves, and the number of vertical moves, or the number of search operations minus the number of opening moves. Table 6 illustrates that concept mappers performed 139 lateral moves, compared with 141 for nonmappers, and 38 vertical moves, with 31 for nonmappers. The differences between the breadth searching and the depth searching in print were not large, with mappers searching in breadth 79% while nonmappers searched in that mode 81%. In electronic searching, the mappers did search 28% in depth as opposed to 16% for the nonmappers. This correlates with the number of opening moves or search strings of mappers being higher: their searches tended to be more sustained than those of the other groups, with less dead-ending after application of the opening move.

Table 6. Breadth and Depth Searches

	Breadth		**Depth**	
	No.	**%**	**No.**	**%**
Print				
CM	118	79	30	21

NCM	92	81	22	19
Electronic				
CM	21	72	8	28
NCM	49	84	9	16
Total				
CM	--	139	--	--
NCM	141	--	31	--

The information measures for breadth and depth searches are as follows:

I(use=print : electronic ; concept mappers | breadth) =
+ 0.60 nats
and
I(use=print : electronic ; nonconcept mappers | breadth) =
- 0.47 nats
and
I(use=print : electronic ; concept mappers | depth) =
+0.22 nats
and
I(use=print : electronic ; nonconcept mappers | depth) =
-0.21 nats

This indicates that concept mappers were using more breadth searching and more depth searching in print compared with electronic but that the difference was particularly pronounced for breadth searching.

A Summary of Conclusions

The information measures shown in table 7 indicate that concept mappers: (1) used print more often than electronic means to search; (2) searched for longer periods of time in SIRS rather than the OPAC; and (3) employed subject heading more often than keyword searching. Measures comparing concept mappers' and nonconcept mappers' performance in print as opposed to electronic environments showed that mappers: (1) used a larger number of search words; (2) had greater variety of search terms; (3) employed opening moves, reformulations, and search operations more often; and (4) executed depth searching more frequently.

Table 7. Summary of Measures of Search Characteristics

Search Characteristic	Concept Mappers	Non-Concept Mappers
Print vs electronic	0.40	-0.36

SIRS vs OPAC	0.96	-1.65
Subject vs key word	0.74	-0.41
Total search word repertoire	0.91	-0.74
Unique search word repertoire	0.61	-0.41
Opening moves	0.72	-0.52
Re-formulations	0.78	-0.57
Search operations	0.79	-0.64
Breadth searching	0.60	-0.47

The difference between the two measures for each search characteristic is the measure of the probability that concept mappers searched more thoroughly and more efficiently. In all cases that probability measured at least half a nat, indicating that the chances were approaching twice as likely that searchers engaged in these functions in print indexes were concept mappers. The sign plus or minus is an indication: conclusive statements cannot be made on the strength of the effect. Since the study defined successful searching in terms of these indicators, findings strongly indicated that the amount of information available was in favor of mappers doing more in their searching, that is, being more thorough searchers who showed a preference for print search tools.

Table 8 summarizes information measures on the number of times per minute opening moves, reformulations, and search operations were performed. Concept mappers performed these operations about the same number of times per minute and made more relevancy judgments while searching in print compared to electronic search tools, which is appropriate given the differing natures of manual and electronic searching. With attention to sign, the negative values were computed for print as opposed to electronic for reasons of consistency and comparison. The measures indicate that the signs of the computations were consistently in favor of the probability that concept mappers would use these operations in electronic searching as opposed to print, the sign being inverted for the calculation of electronic as opposed to print. These characteristics were calculated per minute, indicating rate: mappers were performing the functions faster if they were able to do more per minute. The findings strongly indicated that from these measures the amount of information available was in favor of the mappers doing less per minute in their print searching, with qualitative evidence offering the explanation that they were finding information and thereby conducting efficient searches. The probability of assessing if these results could arise by chance was difficult for a calculation of this nature. The nature of the indication of an information measure reflects the probability that a concept mapper will get one kind of result as opposed to another. However, the proper procedure would be to progressively increase the number of individuals in the sample until the results converge and become approximately independent of the sample size.

Table 8. Summary of Measures of Rates of Search Operations

Search Characteristic	Concept Mappers	Non-Concept Mappers
Opening moves	-0.25	.30
Reformulations	-0.26	.34
Search operations	-0.33	.38

The relationship between the quantification of data and the texture and depth of understanding provided by qualitative data was synergistic in the analytical process that sought to explain as well as describe the search process. Emerging patterns of searching behavior in print and electronic environments were outlined by numerical summaries; texture and color of related qualitative description served to provide a measure of understanding. For example, while characteristics of searching behavior (i.e., search word repertoire, opening moves, and re-formulations) could be quantified to point out differences in print and electronic environments, qualitative data provided explanation for relevancy judgments and connections. The interplay of numerical and verbal descriptions served to push the analysis toward understanding the searching phenomenon in depth; for example, the interdependence of focus formulation and information overload. Qualitative data, through triangulation of students' testimony about their own thought processes with observations of their performance, shed light on the metacognitive aspects of searching. Quantification of the data provided direction and structure, as illustrated by the examination of keyword and subject searching and search word repertoire, which highlighted characteristics of the concept-driven search. In every instance, qualitative evidence supported the findings described through the information measures: concept mappers were more thorough and efficient in their searching, more inclined to concept-driven searching as evidenced by their ability to focus and make connections, and more inclined to make metacognive judgments that led to successful searching.

The searching of concept mappers was more thorough and more efficient for three reasons. Concept mappers reformulated by shifting synonyms and moving from general to specific search terms rather than by changing concepts, so their reformulations were within the focus of the search. They avoided information overload, and they terminated searches because they wanted to read and not because they exhausted their repertoire of search terms.

Analysis of the data illustrates that the most dramatic differences between mappers and nonmappers emerged in electronic searching where the concept mappers:

1. Spent less time searching
2. Searched for fewer and shorter sessions
3. Preferred subject heading to keyword searching
4. Spent less time in the OPAC than in the electronic SIRS
5. Had fewer search words in repertoire of nonrepeated words and in total number of search words
6. Generated fewer opening moves and generated them at a faster rate
7. Generated fewer search strings and generated them at a faster rate

8. Generated fewer reformulations and generated them at a faster rate
9. Generated fewer search operations and generated them at a faster rate
10. Generated fewer relevancy judgments
11. Performed a larger percentage of depth rather than breadth searches

The fact that these differences emerged while students were searching in an electronic rather than print environment indicates that concept mappers managed that environment more successfully than their nonmapping counterparts. They seemed efficient in the way they used their time to perform more search operations per minute and more thorough in consistently applying a more concise repertoire of search terms and in engaging in more depth searching.

Implications of the Study

Concept mapping, as indicated by it strong research history, is effective in strengthening concept formation. In this study, students trained in concept mapping over a period of several months prior to an information search demonstrated greater concept formation, manifested in more efficient and thorough searching behavior. Although the verbal evidence and Fano measures are indicators only, and a larger sample is required to validate preliminary conclusions, this study has demonstrated that concept formation in the classroom affects the information search for those informants in the study.

For the qualitative researcher, this study offers an alternative to classical statistics in hybrid studies. Although the predominance of data generated in a qualitative study is verbal in form, there are quantitative data that are often ignored for lack of a method of treatment for data from small samples. Qualitative researchers do not ignore the significance or possible meaning in the incidence of an event, for example, but have no alternative to presenting raw data, albeit categorized and analyzed for patterns and repetitions. When there is a need to quantify in a more explicit manner, the only recourse for the qualitative researcher is to conduct a hybrid study that marries verbal and numerical data. There is a serious flaw in such an approach; the sample size for an in-depth, qualitative study cannot easily meet the requirements for sample size prerequisite for classical statistical analysis.

Further research is needed to establish the usefulness of information theory in the study of the search process. The use of information theory as a numerical summary of qualitative data has emerged in this study as a useful tool for reducing and interpreting that data in a meaningful way for a small sample size. It also provides a framework for qualitative evidence that points to an explanation of emerging trends. Information theory avoids the pitfalls of Type I and Type II errors of classical statistics since it considers all possibilities. There are strong indications that information measures are viable alternatives for quantification of large amounts of data. It is recommended that in further research the size of the sample is increased until the results are independent of that sample size.

The emergence of qualitative assessment measures in education, namely authentic or performance-based assessment, are endangered by the absence of a method for handling numerical data quantitatively. These methods emerge from the “authentic” learning tasks that, in themselves, become the instruments for assessment as learners apply standards from rubrics that use ratings to measure their attainment of those standards, journals that document process, and portfolios that supply longitudinal evidence of growth. The data in these authentic assessments

cannot easily be pronounced publicly and used politically as evidence in favor of an instructional method. This is a problem for educators, especially library educators, who know that a percentile ranking is a slick way to pigeon-hole student performance, but offers little substantive information with regard to diagnosis and remediation.

Traditional summative assessment methods (i.e., tests and grades) are not adequate tools for the hard-to-measure higher-order thinking skills that are ingrained in information literacy. Even item analyses of tests, while identifying areas of weakness in student performance, do not address the deficiencies or remedial needs of the individual student. Meanwhile, mounds of valuable qualitative evidence accumulating in student portfolios and generated by journals, rubrics, and other qualitative assessments, remain inert beyond their immediate pedagogical applications because they defy quantifiable analysis. Authentic assessment, a powerful teaching method that offers formative assessment data, is overshadowed, and even threatened, by the gargantuan of standardized testing on statewide and national levels.

For these reasons, further research is warranted, based on the findings of this study, to refine and test the use of Bayesian statistics in qualitative research studies, particularly in the sparsely researched area of performance-based library and information literacy instruction. Is an integrated rather than isolated approach to teaching information skills more effective? Do heuristic devices make a difference? How can performance-based assessment, when applied to student project work, affect learning? What is effect of resource-based rather than textbook-based teaching on student achievement? Such a research agenda calls for hard evidence that can substantiate the claims of library educators that one instructional method is superior to another.

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See also:
Mind Mapping FAQ

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