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Methods for MeasurinoooVuC-1(on11.7c)- 0om- 0m S learning takes place. In education, behaviorist theory for programmed instruction, teaching machines, and instruction it encouraged a too-specific approach to tea lessons taught out of the context of their utility.

Cognitive psychologists investigated learning and cre received, processed, and assimilated into the learner' of cognitive development traced the development of t the sensori-motor stage of infancy; the intuitive or pre stage of concrete operations in the elementary school adolescence (Inhelder and Piaget 1958). Piaget descri individuals organized their perceptions into categorie schemata adapt during the learning process through new information into existing schemata, or by accom modified to create new mental structures. Learners v accommodating information in terms of what they al

Piaget 1958). Constructivist theory has grown to provide a rationale for hands-on, active learning; inquiry learning; learning to learn; and performance-based assessment in the classroom. With a paradigm shift from bibliographic instruction to information literacy, this theory supported the process approach to teaching information skills in the academic context of curriculum. The information user is seen as learner through the lenses of information literacy, cognitive, and metacognitive processes.

The behavioral and constructivist schools of thought emerged from educational research that built its knowledge on a philosophical foundation, an ethnographic tradition of observation, and the practical study of human beings. Piaget (1928) and Dewey (1943) observed the child as the object of study as they studied the phenomenon of learning. When the ideas of Thorndike (1903) supplanted this ethnographic approach, psychology as an empirical science became the new foundation for building theory. Thorndike's dictum, "Whatever exists at all exists in some amount. To know it thoroughly involves knowing its quantity as well as its quality" (Lagemann 2000, 57) prodded educational research to mature into an empirical science. The subsequent contributions of Binet (1916), Binet and Simon (1983), Galton (1883), Pearson (1896), Spearman (1904), and Fisher (1935) established quantitative measures as the dominant, and most credible, kind of data. Lagemann criticizes educational psychologists who embraced mental testing: "But having found a technology that could be applied and tinkered with endlessly, they generally avoided questions concerning the value and necessity of sorting students in the first place" (2000, 94). The Eight-Year Study conducted by the Progressive Education Association moved Tyler (1950) to use learning objectives to guide test construction. Fueled by the large number of college applicants and rooted in education's march to empiricism, the Educational Testing Service was born, creating a culture of standardized testing. With the writings of Lincoln and Guba (1985), qualitative methods began to find a place in educational research. The rebirth of qualitative research and philosophical traditions in educational research, along with the adoption of principles of contructivism from cognitive psychology, provide the common ground where educational research and IR studies can find their roots.

This is significant for their respective research agendas since learning theory adopted as a theoretical framework in a research study has a particularly strong effect on that study's methodology.

The behavioral, system-centric tradition in IR studies grew from a bibliographic paradigm: "Information retrieval has concentrated on what matches the system's representation of texts rather than responding to the users' problems and process of information gathering" (Kuhlthau 1993, 1). These studies, conducted largely by engineers and scientists who were pioneers of IR development, relied heavily on probabilistic theory and algorithmic approaches. User-centric studies, on the other hand, were based on constructivist theory and collected data through ongoing interaction with the user. The system-centric school considered relevance too elusive and subjective and rejected it as a criterion for performance testing. On the other hand, user-centric studies explored relevance in the context of the sense-making approach and experimented with relevance judgments prior to accepting or rejecting relevance as a criterion for performance. The dominant research model of the 1960s and '70s emphasized such input processes and components as document representation and retrieval effectiveness. Learning theories derived from cognitive psychology—which grew from concepts such as knowledge states, conceptual framework, and internal representation—constituted a trend away from system-centric views and shifted the focus from relevance to the information needs of the user. The theory of an

anomalous state of knowledge (ASK) described by Belkin, Oddy, and Brooks (1982) counteracted the best match principle. Dervin and Clark's (1987) sense-making approach and Taylor's (1968) user-value approach emphasized the user's perceptions of the information problem and of the utility and value of the system. Progress in sculpting a theoretical framework based in cognitive psychology culminated in Kuhlthau's (1986) model for the information search process, which used Kelly's (1963) theory of constructs and included the thoughts, actions, and feelings of the information seeker. IR studies used interviews, think-alouds, observation, journaling, concept mapping, and other methods that yielded qualitative data.

Constructivist learning theory and qualitative investigative methods have emerged as powerful research tools that have transformed practice in educational and information skills programs, shortening the distance between the classroom and the library.

The Quantitative-Qualitative Divide

The debate between quantitative and qualitative research is bogus in that the value of their respective methodologies lies not in their relative merits, but in their appropriateness to the research question at hand. There is a tension, however, that arises from practical, rather than theoretical, considerations. At the root of this tension is an overconfidence in what can be quantified and a lack of confidence, or interest, in more cumbersome verbal data.

A practical consequence of qualitative research's lack of credibility is the inappropriate use of quantitative research findings as they are applied to all points of analysis in education—including learner, classroom, and school—to produce results that raise concerns about validity. On a political level, the bias for the quantifiable, which offers a succinct interpretation of data, puts this kind of data in headlines. Although there are appropriate uses for norm-referenced tests, results are often interpreted in terms of individual student achievement. Funding, and even the very existence of marginal schools, may be determined not on how well students are progressing
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level, whatever the data give, rather than say, “reject it because it did not reach the magic number

Probability P(A) is the simple probability or self probability of event A. In the limit of large numbers this is given by n(A)/N, the number of times event A is counted divided by N the total sample size. Note that N will be:

$$N = n(A)+n(B)+n(C)+.$$

summed over all events A,B,C, etc. For example, P(blue eyes) = probability of occurrence of a person with blue eyes.

Probability P(A,X) is the joint probability, or A and X—the probability that they will be counted together. For example, P(blue eyes, boy) is the probability of counting a blue-eyed boy.

A joint probability could be represented as:

$$P(A, X) = P(A) * P(X)$$

Bayes' refinement of the Fano measure included the introduction of probability P(X|A) is the conditional probability of X on A. For example, P(blue eyes|boy) is the probability of finding blue eyes, given that the person is a boy. It may be calculated from P(A) and P (A,X) by

$$P(X|A) = P(A,X)/P(A)$$

P(A|X) could be obtained by only counting eye color in the set X, boys. Then

$$P(A|X) = n(A,X)/n(X)$$

The number of blue-eyed boys is divided by the total size of the sample, here the number of boys. Some condition X is, in a sense, always present behind the scenes: It is the set in which you perform your counting. In other words, in statistical sampling you are concerned about the representativeness of X.

Mathematical probability is based on a model that assesses the frequencies of sequences of events. Conditional probabilities provide a refinement of the concept so that particular features of a situation are taken into account when probability is assessed (Parsaye and Chignell 1988). If we rely on a frequency view of probability, however, the more features of a situation we consider, the more unique it is and thus there are fewer previous cases to draw on in estimating the probability. This, in turn, reduces our confidence in the accuracy of the probability assessment.

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 Chignall 1988). Bayes' (Parsaye and Chignell 1988) equation is a special application of conditional probability as described above:

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quantities, as well as to model how the information measures, which are a kind of statistic, can guide the analysis of verbal

Figure 1. Conceptual Model of the Study

The theoretical framework drew from the research traditions in education and information science studies based on cognitive psychology. Figure 2 illustrates the components of this framework.

taken of the fact that a particular type of education or training might have a beneficial effect in favor of some activity A, even if the student still spends less time in that activity A than in other activities. 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; for example, the probability that the student will be found in the specified pursuit, such as use of print, at any time. The ratio of time in one activity as opposed to another is, in effect, compared with the ratio that we expect if we pool (and thus choose not to distinguish) concept mapping from non-concept mapping students. Logarithms are taken consistent with the theory of information posed by Fano, and in this case natural (base e) logarithms resulting in natural units, or nats, of information. The formula used is as follows:

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

This could be read as “the amount of information provided by concept map training that the student will use print at any time as opposed to electronic means.” The semicolon means “information provided by” and the colon means “as opposed to.” Substituting the times, we obtain

log [220/96] – log [386/252] = +0.40 nats

as the measure of that information. Because we are estimating probabilities from data in regard to time spent, it is customary to express results as being conditional on that assumption about data. To do this, a vertical bar is used to express the notion of conditional on. That is, we may write

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

This means the information, being positive, is in favor of 1(m)-2(e)4a9.08 0 Td >>BDC(ovi)-3(pde)4(us)-1(e)
c9.73 -1.15>>BDC(ovi)n fav2(d be)4(]TJ Tud t)-2(o t)-2(s)-1(, of (oni

direction for your party even if your party doesn't get elected. Note also that basic information theory does not make statements about significance, only about the amount of information available, and represents a weight of evidence, loosely analogous to stating the level of confidence limit at which a given hypothesis would become acceptable in classical statistics. The above measures correspond to the kind of value one would obtain if there was expected to be no bias and the results showed mappers to spend 50 percent more time in print than in electronic, which in this example is consistent with the impression easily gained from the diagram. In contrast to classical statistics, the information theory approach likes to consider both Type I and Type II errors as of relevance, and this is implied in the above approach.

Although not used by Fano in that it loses comparative detail in relation to what is expected, subtracting the second ki4(s)-1(t)-2(a)4((u914(g)6(our024(c)4c)4(e)4(,)-10(a)4(nd t)-22T [(s2(l)j Ei0)6(ons)5

Figure 6. Searchers' Best and Worst Searches

P = Print Indexes
E = Electronic Indexes
NS = New Scientist Index
OPAC = Online Public Access Catalog
RG = Readers' Guide Index
SIRS = Full-Text Database
CI = Critical Issues Index

Scrutiny of the search tools offered some clues for preferences. From the four mappers who preferred print indexes, three stated the *New Scientist* as their preference, whichw 1523

Mappers tendency to spend more time in print indexes was directly related to:

1. the high quality of scientific, technical information retrieved through print indexes;
2. the large number of sources the indexes yielded; and
3. the rich supply of search terms the indexes offered by cross-references and titles.

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 1. Mappers searched a total of 24 sessions, 7 of which were electronic searches, which represents 29 percent of their total number of search sessions, compared with the nonmappers, who had 9 electronic search sessions, or 53 percent of their total number of search sessions. For print sessions, the reverse was true, with mappers spending 17

Why did mappers search about one-third of their time on electronic tools while nonmappers searched almost half their time on computers? Why did mappers prefer print indexes while nonmappers spent considerably more time on electronic searches? Did electronic methods compensate for nonmappers' lack of conceptual maps? Do electronic methods benefit mappers or nonmappers?

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There was a greater probability that 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 conduct subject heading rather than keyword searches. In print, as opposed to electronic searching, measures showed mappers applied a larger number of search terms; employed opening moves, reformulations, search operations, and relevancy judgments more often; and executed more depth than breadth searching. In all cases probability measured at least half a nat, 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.

A summary of information measures on the number of times per minute opening moves, reformulations, and search operations were performed is reported in table 3.

Table 3: Summary of Measures of Rates of Search Operations

Search Operations	Mappers	Nonmappers
Opening moves	-0.25	+0.30
Reformulations	-0.26	+0.34
Search operations	-0.33	+0.38

Data indicated a trend: mappers will perform these operations about the same number of times per minute and make more relevancy judgments while searching in print as opposed to electronic search tools, which is appropriate given the nature of manual versus electronic searching. With attention to sign, negative values were computed for print as opposed to electronic for reasons of consistency and comparison. The resulting measures indicated that the signs of the computations were consistently in favor of the probability that mappers would use these operations in electronic searching as opposed to print, the sign being inverted for the calculation of electronic as

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 what was going on in 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—such as search word repertoire, opening moves, and reformulations—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 key word 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: 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 metacognitive judgments that led to successful searching.

The searching behavior of mappers was more thorough and more efficient if they:

- 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;
- avoided information overload;
- made more connections in a balanced and eclectic pattern from print and electronic search tools; and
- terminated searches because they wanted to read and not because they exhausted their repertoire of search terms.

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

- spent less time searching;
- searched for fewer and shorter sessions;
- preferred subject heading to key word searching;
- spent less time in OPAC than in the electronic index;
- had fewer search words in the repertoire of nonrepeated words and in total number of search words;
- generated fewer opening moves and generated them at a faster rate;
- generated fewer search strings and generated them at a faster rate;
- generated fewer reformulations and generated them at a faster rate;
- generated fewer search operations and generated them at a faster rate;
- generated fewer relevancy judgments; and
- performed a larger percentage of depth rather than breadth searches.

Kuhlthau, C. C. 1993. *Seeking meaning: A process approach to library and information services*. Norwood, N. J.: Ablex.

Kuhlthau, C. C. 1986. *Facilitating information seeking through cognitive modeling of the search process*