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The development of enhanced information retrieval strategies in undergraduates through the application of learning theory: an experimental study

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In this paper, I describe an experimental study on the efficacy of concept-based instruction in developing information retrieval skills in undergraduates. The subjects were 254 first-year undergraduates at the University of Canberra, Australia. The study followed the experimental design of a pre-test/post-test control group. The experimental group was taught information retrieval from electronic databases using teaching strategies grounded in learning theory.

Results suggested that in the teaching of information retrieval, a concept-based approach is significantly more effective than a traditional, skills-demonstration approach. This effectiveness was both in terms of increasing knowledge of the search process and in terms of improving search outcomes. These results are of particular interest, given the vast amount of information to which students now have access through electronic databases and internet sources – and the corresponding need to be able to locate material relevant to an information requirement.

‘”Well! That’s all there is in the computer!” End-users sometimes do not realise that the computer finds only what they specify, not necessarily what they want’ (Kirby & Miller 1986, in Lancaster et al 1994, p 382). Borgman et al (1984, p 19) foreshadowed the difficulty that end-users would encounter with computerised

information retrieval systems when they observed that these complex systems require 'intensive training and regular use' to be utilised competently. They predicted that online systems of the future would be operated on a large scale by people seeking their own information: the end-users. This prediction has in fact proved accurate; undergraduate students now have direct access to a staggering amount of information through electronic databases and internet sources. The question arises: how can we most effectively teach novice searchers the information retrieval skills they require in order to take advantage of this wealth of information?

Instruction in information retrieval from electronic sources until the late 1990s was focused primarily on skills development. A number of researchers addressed the efficacy of demonstration versus hands-on computer instruction, for example: Barbuto and Cevallos (1991); Davis and Bostrom (1993); and Ramaoka (1995). These studies, however, compared only different ways of teaching database-specific skills, or *procedural*, knowledge. Others, for example Lawson (1989), compared the efficacy of computer-assisted instruction to a library tour for general bibliographic instruction. Lawson found that computer-assisted instruction was a useful alternative to a tour, but not better than a tour. Their results indicated little difference between treatment groups. In this researcher's view, this is because the actual mode of delivery of skills training will not affect search performance substantially. What *will* influence search performance is concept-based knowledge of the information retrieval process, database limitations, and problem-solving skills.

A skills-based focus, developed originally to deal with the introduction of computer databases to the library, is no longer adequate to address either the volume of information now available to students through such databases, or the apparent preference of these (mostly) novice end-users to conduct searches on their own, with minimal instruction. The ubiquity of the internet and its popularity as a search tool further highlights the inadequacy of a skills-based approach to information retrieval, and a shift in conceptualisation from 'skills' to 'information literacy' has occurred.

A comprehensive discussion of the elements of information literacy is provided by Spitzer et al (1998), building on the work of Doyle (1994, in Spitzer et al 1998). Definitions of information literacy are almost as numerous as writers on the topic, but these definitions do not vary on the *type* of core skills comprising the construct – various thinking and sense-making processes – as much as on the *range* and *complexity* of skills that is included, or on how these thinking skills themselves are defined. For example, the State University of New York Council of Library Directors (1997, in Spitzer et al 1998, p 24) defined information literacy as the ability to 'recognize when information is needed and to locate, evaluate, effectively use, and communicate information in its various formats'. In this definition, thinking strategies such as decision-making (used in recognition of an information need, effective use of information, and selecting communication channels) are implied; only the critical thinking skill of evaluation is explicit.

Lenox and Walter (1992, in Spitzer et al 1998, p 26) go further, and assert that information literacy requires a range of critical thinking skills: the ability 'to sort, to discriminate, to select, and to analyze the array of messages that are

presented'. Peacock (2001, p 27) states explicitly that the aim of information literacy is 'to promote critical thinking, increase information competence and equip individuals for lifelong learning'. Kuhlthau (in Stripling 1999, p 7) takes a wide view, describing information literacy as 'the ability to construct one's own meaning from an information-rich environment'.

However widely or narrowly defined, information literacy has been much debated in recent literature as a generic outcome of higher education (Bruce 1997, 1998, 2000a, 2000b; Bundy 1999; Halpern 1998; Julien 1998; Watson-Boone 2000; Webber & Johnston 2000; Yerbury & Parker 1998). As with definitions of information literacy varying not so much in type of skills involved but in their degree of inclusion, the question of the importance of teaching information literacy is not at issue; rather, the matters under discussion are where, how and what to teach. The debate on information literacy in higher education has culminated in the development and publication of a first edition of Australian *Information literacy standards* (Council of Australian University Librarians 2001).

Skills-based instruction, then, seems to be inadequate to develop information literacy. Another line of research over the last 10-15 years, more closely aligned with the development of the broader requirements of information literacy, is that which deals with the efficacy of concept-based teaching of information retrieval. As Bruce (1998) observed, these studies are comparatively few in number, but interest in this style of teaching, and recognition of the role of problem solving in the search process, is increasing.

Studies exploring a cognitive, conceptual approach to bibliographic instruction emphasise the need to teach end-users how to develop a conceptualised understanding of the search process. For example, Penhale and Taylor (1986) found that the major problem faced by novice searchers is the development of a good search strategy. In that study, 18 undergraduate biology students were assigned randomly to search one of four topics using online databases, and their results were compared with the searches of four reference librarians on the same topics. Results indicated a significant difference in recall of relevant information between the novice and the expert searchers. Recall was defined as 'the percentage retrieved of the total relevant set, with the total relevant set defined as the number of highly or moderately relevant articles found in all the searches combined' (Penhale & Taylor 1986, p 213). This difference in recall was attributed by Penhale and Taylor to the greater number of search terms and synonyms used by the reference librarians. They concluded that 'the major problem faced by novice searchers is the development of good search strategy' (Penhale & Taylor 1986, p 215).

Sylvia and Kilman (1991) advocated a conceptual approach to bibliographic instruction to counteract the overload of information that can occur using CD-ROMs. They observed that after the installation of CD-ROM databases in the library at St Mary's University, Texas, student end-users were unable to use them effectively, due to lack of a conceptual understanding of the database 'information universe', how databases were organised, and how to formulate search strategies. Sylvia and Kilman observed that the CD-ROM format became a barrier to search

success, as without a conceptual strategy, end-users suffered from information overload caused by simple keyword searches yielding far too many items. The decision was made to improve end-user education by establishing cognitive learning objectives, such as how to define and select databases, and selecting Boolean operators. Although results were not quantified, Sylvia and Kilman (1991, p 46) concluded that 'user reaction is reinforcing our professional observation that what we commonly called 'CD-ROM information overload' is reduced through the use of ... conceptually grounded search strategies'.

This finding, however tentative, goes some way toward resolving the issue mentioned by Sein and Bostrom (1989, in Balaraman 1991, p 284) as to the 'puzzling display of weak effects of conceptual models'. Sein and Bostrom observed that the efficacy of conceptual models is supported by theory, yet empirical evidence of their use is scanty or ambiguous.

Zahner (1992) conducted a doctoral study with 190 first year subjects in the United States of America at Valdosta State College, Georgia, using an experimental research design. In that study, Zahner investigated, inter alia, the efficacy of a 'cognitive strategies' framework for the teaching of library skills, emphasising a process orientation to research and problem-solving skills.

The 'cognitive strategies' framework emphasised the process of the search rather than the use of information sources specifically, and the need to view searching as a problem-solving process. Affective (emotional) and metacognitive dimensions of the search process (evaluation of thinking processes and progress towards problem solving) were also discussed. Over three tutorial sessions, subjects were taught a 'Focus, Format, Find and Evaluate' strategy for searching. Subjects worked with peers in these instructional sessions. In the 'Focus' phase, subjects generated a search question. In the 'Format' phase, subjects chose appropriate information sources to research the question, such as books, journals or newspapers. In the 'Find' phase, subjects generated strategies to find relevant information, using library catalogues to find citations. Physical location of materials was discussed. In the 'Evaluate' phase, the quality of located sources was evaluated using a checklist. Results suggested that this 'cognitive strategies' instruction resulted in significantly better research paper bibliographies than those generated by the 'traditional approach' treatment group.

The research I present here should provide evidence either for or against the use of conceptual models in the teaching of information retrieval.

Method

This study followed a pre-test/post-test experimental design, using a sample of 254 undergraduate first-year subjects at the University of Canberra, Australia. The experimental treatment group was taught a short concept-based module in order to determine whether this instruction would result in subjects being able to conduct more successful searches than control group subjects, who were taught skills-based search techniques only.

Table 1 below summarises the hypotheses tested, stated in the null form, and the instruments used to enable measurement.

Table 1: Summary of hypotheses (null form) and instruments of measurement

	Hypotheses (null form)	Instruments
1a	There is no difference between experimental and control groups on electronic database knowledge in the pre-test	Survey 1, section 2: Electronic database knowledge (pre-test)
1b	There is no difference between experimental and control groups on electronic database knowledge in post-test 1	Survey 2, section 2: Electronic database knowledge (post-test 1)
2	There is no difference between experimental and control groups on search performance	Information Retrieval Assignment (post-test 2)
3	Good searchers do not identify more concepts, use a greater number of relevant databases, and construct more effective search strategies, than do poor searchers	Information Retrieval Assignment (post-test2)

Data collection

Data were collected by means of three instruments: Survey 1 (pre-test); Survey 2 (post-test 1); and an Information Retrieval Assignment (post-test 2). Survey 1 was completed in Week 2 of semester tutorials. The survey was used to gather baseline information on intervening variables such as level of education; age; gender; computer anxiety; levels of knowledge of electronic database searching; problem solving; and to a limited extent, cognitive maturity.

Survey 2 (post-test 1) measured knowledge of electronic databases, and was administered two weeks after the experimental module, which was taught in Week 2 tutorials. The Information Retrieval Assignment (post-test 2) was distributed to all subjects in Week 2. Completed assignments were submitted in tutorials in Week 4. The assignment required subjects to locate citations for articles that were 'highly relevant' for each of three search topics. These topics were of varying difficulty; Topic 3 was the most difficult.

Population and sample

The experiment was conducted in the first half of Semester 1 (1997), with first-year undergraduate subjects. This timing was chosen in order to determine the impact of teaching strategies on 'novice' searchers.

The population was defined as all first-year undergraduate students attending the University of Canberra. Subjects were not randomly chosen for this research as the nature of the experiment required tutorial groups to be formed in order for the experimental module to be taught; drawing subjects randomly from the population was not practicable. However, the researcher was able to conduct the experiment using a very suitable pre-formed sub-unit of the population. This sub-unit comprised all students registered in the semester-long unit Communication Interface 1.

This unit was suitable because 254 students were enrolled. Students signed on to one of 18 tutorials, and this enabled a strong experimental design to be implemented, as random assignment of these groups to either experimental or control treatments was possible. Even though this sample was a 'convenience' sample (Sproull 1995, p 119), in that it was a cohort of students already formed, the researcher considered that its parameters enabled conclusions to be extrapolated to the population it represented with some confidence. Due to the sample size, and the ability to assign subjects randomly to treatment groups, intervening variables normally limiting the implementation of an experimental design could be controlled.

The study was of a 'single blind' design. The researcher was aware of which tutorials were experimental treatment groups and which were control groups - but the subjects were not.

Variables

The independent variable was the teaching module designed to determine whether concept-based instruction (as opposed to skills-based instruction alone) would influence understanding of electronic databases, search behaviour and search outcomes. The dependent variables were performance on the two post-tests: Survey 2, designed to measure any change in knowledge of electronic databases; and the Information Retrieval Assignment, designed to enable actual search strategies, behaviour and outcomes to be measured.

Intervening variables suggested in the literature that might impact on the cause-effect relationship between the independent and dependent variables included: previous knowledge of electronic databases; age; and human factors such as academic major; computer enjoyment; and computer anxiety. In order to allow quantification of these variables, the researcher included questions on all of them in the first section of the pre-test (Survey 1). These variables were controlled as far as possible by ensuring that the sample size was large, and that assignment of subjects to experimental and control treatments was random.

For search strategy, variables rated on the Information Retrieval Assignment included: *Number of concepts*; *Number of inappropriate concepts*; *Number of relevant databases*; *Number of irrelevant databases*; *Number of databases* (total); *Number of synonyms*; *Number of reformulations*; *Use of truncation* - correct, incorrect, mixed or not used; *Use of Boolean operators* – AND, OR, NOT; *Suitable search strategies* - yes/no; and *Self-evaluation of search success.*

For evaluating search success, variables rated included: *Relevance* (inadequate, marginally adequate, adequate, good, superior); *Source* (same rating); and overall *Search success* (same rating).

The Module

The teaching module (the 'Module') was designed as the experimental treatment that would influence both search *knowledge* and search *behaviour*.

The Module was delivered in Week 2 to experimental treatment groups, in computer laboratories where all students had their own computer through which electronic databases could be accessed. Content was structured using teaching strategies grounded in Cognitive Learning Theory (Jacobson & Jacobson 1993). These strategies included the development of concepts rather than skills; use of analogy to relate new to existing knowledge; introduction of complexity; discussion of examples and exceptions; modelling of desired behaviours; and the opportunity to implement the new knowledge.

The first step of the Module comprised a 30-minute Powerpoint presentation, the aim of which was to encourage subjects to develop a realistic concept of the strengths and limitations of electronic databases, and appropriate search techniques.

In the presentation, analogies were used to assist subjects to develop a 'mental model' of database structures and content.

Following the tutor's presentation on concept formation, the second step of the Module dealt with question analysis and query design. A conceptual framework for search construction, using a problem-solving heuristic, was introduced. A sample search topic was given, and a search worksheet distributed. Subjects were guided through the processes of defining the search question; breaking the topic into main concepts, including the identification of any implied concepts; finding synonyms for each concept; and using Boolean operators.

After search strategies had been developed for the sample topic, subjects were asked to consider appropriate databases on which to run the search. The subjects conducted searches. The tutor demonstrated how the same search executed on different databases yielded very different results. The point was made that expert searchers can spend more time preparing a search than actually executing it.

After the Module, all subjects had two weeks to complete the Information Retrieval Assignment, which was integrated with Communication Interface 1 teaching aims.

Limitations

The researcher acknowledges the difficulties inherent in conducting an experiment in a natural setting such as a university library and computer laboratory. Limitations included time constraints and technology. The researcher had limited access to

students, and so content of the pre-and post-test surveys had to be tightly controlled in order to minimise administration time, whilst still enabling meaningful measurement of problem-solving ability and knowledge of electronic databases.

The technology constraint manifested as two days of unscheduled server 'downtime' over the weekend preceding the due date for the Information Retrieval Assignment. However, despite this, of the 254 subjects, 199 submitted assignments as requested - a very satisfactory response rate of 78%.

Results and discussion

Demographic data gathered in the pre-test indicated that the typical participant was a female high-school leaver aged under 20 years, with no experience in using an electronic database to search for information.

A t-test was used to test hypotheses 1 and 2. The results suggested that there was no difference between experimental and control groups on electronic database knowledge on the pre-test. Hypothesis 1 was therefore accepted. A significant difference was indicated between the experimental and the control groups on post-test 1. The mean for the control group was in fact *lower* by 4.7% on Survey 2 than on Survey 1. The mean for the experimental group was 3.2% *higher* on Survey 2 than on Survey 1. Overall, the experimental group performed 7.9% better than the control group on Survey 2. The result was highly statistically significant ($p = .0018$). Hypothesis 2 was therefore rejected, and the conclusion drawn that the Module may have been useful in improving subjects' electronic database knowledge.

Significant results for Hypothesis 3, regarding differences between treatment groups as measured by the Information Retrieval Assignment, are summarised in Table 2 below.

Table 2: Significant differences between experimental and control groups for each search topic

Topic	Variable	p-value
Topic 1	**Number of concepts**	**.039**
	Use of truncation	**.001**
	Self-evaluation of search success	**.05**
Topic 2	**Number of concepts**	**.000**

Topic 3	**Number of inappropriate concepts**	**.033**
	Number of databases searched	**.015**
	Use of Boolean operators	**.004**

Of the twelve variables examined, only the *Number of concepts* (appropriate or inappropriate) showed a significant difference between experimental and control groups for all three search topics. However, that variable was an important one, as previous research (Bates 1986; Borgman 1986; Lancaster et al 1994; Saracevic 1971; Spink 1995) has suggested that failure to identify appropriate concepts is one of the main reasons for search inadequacy.

It is possible that the experimental Module assisted subjects to consider the context of the search question, and what its implied concepts were, thus overcoming a common problem with searching: failure to consider context. Saracevic and Kantor (1988), for example, found that the worst recall for search intermediaries resulted from using only words from written questions, taken as search terms.

The differences between experimental and control groups on the variables *Use of truncation* (Topic 1), and *Use of Boolean operators* (Topic 3) were also significant. The experimental Module, then, may have been successful in addressing the failure of end-users to correctly use truncation and Boolean operators. These were two of the common errors in end-user searching identified by Wildemuth et al (1991) in their study of search strategies employed by 26 medical students.

Wider concept identification, more frequent use of truncation and use of more complex Boolean operators by the experimental group did not however translate into better overall search *strategies*, or search *success*. Search success was slightly better for the experimental group, but not significantly. However, the fact that there was a difference on Topic 3 is important, as this topic was rated by the researcher prior to the conduct of the experiment as being the most difficult of the three search topics. This supports Borgman's (1986) results, in which concept-based instruction influenced performance on difficult search questions, but not on simple search questions.

With regard to search topic difficulty, it would seem that with a straightforward search question, fewer synonyms and search reformulations are required in order to reach a satisfactory search outcome than if the search question is complex. Again, these findings support those of Wildemuth et al (1991), who found that differences in search strategies are elicited by different problems.

With regard to the number of reformulations used, findings revealed a significant weak positive correlation between the *Number of reformulations*, and the *Number of concepts*; *Number of inappropriate concepts*; and *Number of synonyms*. This finding was not surprising, as the more concepts (appropriate or otherwise) and synonyms that are identified by the searcher, the more recombinations of these

words can be made. The finding was interesting, however, as it reinforces the importance of concept and synonym identification in the search process.

It seems that the greater the number of reformulations of the search topic, the higher the likelihood of relevant information being found - up to a point. Two provisos remain in this regard: firstly, that the reformulations are correctly structured; and secondly, that the searches are performed on appropriate databases.

With regard to the first proviso, the process of reformulating is in the researcher's view analogous to a principle of cybernetics described by Morgan (1986, p 86). According to Morgan, the programming in cybernetics that enables a robot, for example, to pick up a pen, works by having the robot 'failing *not* to pick it up'. When instructed to 'pick up' a pen, the robot's 'hand' moves through many corrections until it finally touches the pen. This is a process of error elimination.

In the researcher's view, the process of an end-user reformulating search strategies is analogous; eventually, the end-user 'fails *not* to miss' relevant articles. The more concepts and synonyms that are identified and correctly combined, the greater the likelihood of search success; although this relationship holds only up to a certain point. For example, Wildemuth et al (1991) found that as search experience increased, the number of search strategies (reformulations) decreased. This was also the case in the present study. On all three search topics, subjects who reported that they used electronic databases 'regularly' in the pre-test (Survey 1, Section 1) had a lower range and mean on the variable *Number of reformulations* than did subjects who 'never' used electronic databases.

These findings support the researcher's proposition that information processing theory, in particular 'pattern recognition', is applicable in the information retrieval context. Findings of Wildemuth et al (1991) and of Wildemuth et al (1995) - to the effect that searching efficiency develops over time - also support that proposition. Pattern recognition refers to the ability of a subject to identify relevant patterns or relationships in a given situation. This recognition is far better in experts than that of novices, who typically waste time on irrelevant information (Glaser 1990; Holyoak, in Osherson & Smith 1990). The number of reformulations devised by subjects in the present study who used electronic databases 'regularly' would tend to support this theoretical structure; the amount of practice subjects had accrued with electronic databases made their searches more efficient.

It appears that it is the concept identification stage of the information retrieval process that influences reformulation. Instruction in the process of concept identification (which was included in the experimental Module) may therefore assist in overcoming the difficulty that novice searchers have when reformulating strategy, as reported by Wallace (1993) and Penhale and Taylor (1986). Further, this instruction would also address the findings of Lancaster et al (1994) to the effect that search problems were not so much caused by logical errors, but by search term identification, as end-users in that study were found to search too literally. As subjects in that study were academics and graduate students, it is likely that the

problem with search term identification would be even greater with novice undergraduate end-users.

With regard to the second proviso about the number of reformulations and search success, any aspect of the search strategy, including the number of reformulations attempted, will fail if the wrong databases are chosen to conduct the search. It is essential that any instruction in information retrieval clearly explains what databases are, what they contain, and their limitations. The point needs to be made in any information retrieval instruction that computer information retrieval (ie, the execution of a search command) is nothing more than a complex pattern-matching routine; it is the end-user who has to think.

This point is even more important considering the rapid spread of general access to the Internet, and its use in information gathering. Information sources on the Internet are far less structured than the database library on which the current study was conducted.

Such instruction may also help to overcome the problem with database selection identified by Jacobson and Jacobson (1993); viz, that too much choice in databases may create anxiety in end-users, and the full range of possibilities available to searchers may therefore not be investigated because of the lack of an apparent easy route.

On this point, a significant difference was found between experimental and control treatments on the variable *Number of databases* - again, on Topic 3. In order to answer Topic 3 successfully, a database combining sociology and technology areas had to be identified, and such a search path was not immediately obvious unless the subject had realised that the question was one involving sociology, not simply computer technology. The experimental group had been instructed in the importance of identifying implied and explicit concepts in a search question (the first stage of the search process), and in selecting appropriate databases (the second stage of the search process).

The final variable on which significant differences were observed was end-user self-evaluation of search success. For Topic 1, the experimental group and the researcher-rated scores were similar; the control group overrated their success. Topic 1 was a moderately difficult topic; the experimental group had been instructed about evaluating searches in the experimental Module. For Topic 2, self-ratings for both treatment groups were similar to those given by the researcher. Topic 2 was the most straightforward search topic, and the one completed most successfully by both treatment groups.

For Topic 3, both control and experimental groups over-rated their search success. A possible reason for this optimism is that many articles were retrieved, and resulted in participant perception of search success. However, search *precision* (number of relevant citations found in relation to the total number found) was not high; and precision was a factor considered by the researcher, but possibly not by the less experienced participants. Although the term ‘precision’ had not been used in

the Module, the importance of evaluating search results for relevance to the topic had been included on slides in the Powerpoint presentation. Further, in the written instructions for the Information Retrieval Assignment, participants were told to locate 'highly relevant' articles. It may be, however, that further discussion and examples of what constitutes 'relevance' would in future modules make students more aware of its importance to search success.

In addition to the significant differences discussed above, results indicated that the means of the experimental treatment group were higher than that of the control treatment on 16 of the 21 variables measured by frequency of occurrence (see Table 3). In Table 3, the bold type indicates where the means for the experimental group are higher than those for the control. Significant p-values are also in bold. Four of these values were significant. Three of the significant differences occurred in relation to concept identification. The experimental group means were higher than those of the control group on all seven variables determined by frequency for Topic 3, the most difficult search topic.

Table 3: Variables determined by frequency: experimental and control group means

	Experimental mean	**Control mean**	**p-value**
Topic 1			
Number of concepts	**3.15**	**2.74**	**.039**
Number of inappropriate concepts	**0.41**	**0.30**	**.211**
Number of relevant databases	**1.90**	**1.93**	**.856**
Number of irrelevant databases	**1.03**	**0.86**	**.762**
Total number of databases	**3.01**	**3.49**	**.409**
Number of synonyms	**0.58**	**0.44**	**.317**
Number of reformulations	**5.00**	**4.50**	**.502**

Topic 2			
Number of concepts	**2.80**	**2.47**	**.000**
Number of inappropriate concepts	**0.22**	**0.17**	**.345**
Number of relevant databases	**2.23**	**2.43**	**.522**
Number of irrelevant databases	**0.90**	**0.86**	**.944**
Total number of databases	**3.35**	**3.51**	**.705**
Number of synonyms	**0.52**	**0.34**	**.133**
Number of reformulations	**3.68**	**3.81**	**.825**
Topic 3			
Number of concepts	**2.30**	**2.28**	**.903**
Number of inappropriate concepts	**0.69**	**0.50**	**.033**
Number of relevant databases	**2.04**	**1.58**	**.290**
Number of irrelevant databases	**1.87**	**1.69**	**.680**
Total number of databases	**4.20**	**2.89**	**.015**
Number of synonyms	**0.87**	**0.60**	**.129**
Number of reformulations	**4.56**	**4.05**	**.477**

With regard to Hypothesis 3, it might therefore be concluded that the Module helped participants to develop search techniques that were used by naturally good searchers.

Finally, and most importantly, what is also apparent from the current study is that information retrieval, to be successful, requires not only teaching of question analysis, a problem-solving heuristic and search strategy design; it also requires teaching of concepts and skills involved with the broader spectrum of information literacy: critical thinking skills, and involving evaluation of sources for credibility and relevance.

In 1999, I conducted Phase 2 of this study, in which I again developed teaching modules grounded in learning theory. In this second phase, subjects were 70 second-year undergraduates. The same experimental design was utilised; additional teaching modules were employed to address the development of critical thinking skills in the context of information retrieval, in order to determine whether subjects in the experimental group would retrieve journal articles relating to the two given research questions that were from more credible sources - and more relevant to the search topics - than those retrieved by the control treatment group.

T-tests of independent-samples indicated that there was a statistically significant difference in the number of credible sources used by the experimental group compared to the control group on Topic 1 ($p = .024$). There was also a statistically significant difference in the number of relevant articles located by the experimental group than those located by the control group ($p = .002$).

Conclusion

The results indicated that, on one or more of the search topics, a number of variables varied with type of instruction. These included: *Number of concepts* (appropriate or inappropriate); *Use of truncation*; *Use of Boolean operators; Number of databases*; and *Self-evaluation of search success.* The experimental Module - grounded in learning theory and emphasising a concept-based approach to information retrieval - appeared to influence search strategy formulation, search execution and subject self-perception of search success, supporting findings of two earlier experimental studies. The first of these was by Kohl and Wilson (1986), who found a significant difference between a 'cognitive strategies' instruction style and a 'traditional' style. The second was by Zahner, who in 1992 conducted a study on 'research process orientation', in which the process of the search was emphasised, rather than the information sources in general. The findings of that study suggested that this 'cognitive strategies' instruction resulted in subjects generating significantly better bibliographies for their research papers than those of the 'traditional approach' treatment group.

Further, the results of Phase 2 of this study suggest that if wider aspects of information literacy – such as critical thinking - are taught, search *success* will also improve.

Replication of these results with a similar undergraduate cohort, and the conduct of a similar experiment with subjects of other ages and at other levels of education, would provide further evidence for or against the efficacy of grounding teaching strategies in learning theory when providing instruction on information retrieval.

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