Undergraduate information literacy: a teaching framework.

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Abstract:

In this paper, a framework for the teaching of undergraduate information literacy is proposed. This framework has been developed as a major outcome of the author's PhD research into information literacy issues in general, and an aspect of literacy--information retrieval--in particular. Literature from two disciplines was reviewed as background to the research: cognitive psychology; and information retrieval. Arising from this theoretical background were four main 'prongs' of research: the development of a two-stage explanatory model of the information retrieval process (based on information processing theory); a series of concept-based teaching modules (grounded in learning theory) testing the efficacy of that model in a large experimental study; an analysis of the role of cognitive maturity in the information retrieval process (based on tenets of developmental theory); and finally, the development of a framework for the teaching of broader aspects of information literacy, which framework drew together all theoretical aspects of the research.

Full Text:

A focus of teaching and learning in higher education today is the importance of developing 'generic' abilities, such as critical thinking, problem-solving, and information literacy. These abilities have been discussed widely in recent literature. (1) A second focus of higher education is the process of learning; for example, what teaching strategies will result in optimal learning outcomes?

In this article, it is suggested that information literacy is a generalisable skill that subsumes both critical thinking and problem-solving. (2) A framework (the 'framework') for teaching these capabilities, grounded in the tenets of cognitive psychology and learning theory, is proposed. The components of the Framework have been tested empirically in three experimental studies, the results of which are summarised later in this paper.

The Rise of Information Literacy, and Critical Thinking Rediscovered

Over the past decade, the comparatively narrow field of 'research skills', once considered optional in the undergraduate curriculum, has evolved into the broader concept of 'information literacy'--a group of competencies essential to academic success, and beyond that, to performance in the 'information society'. Elements of information literacy--researching, analysing, interpreting, disseminating--have always been integral to the development of the mental discipline that characterises a successful graduate. However, the redefinition and reclassification of a range of cognitive abilities into the cluster of skills now referred to as information literacy, is a response to the centralisation of the importance of information in today's knowledge-driven society. Never before has the ability to discriminate between information sources as to credibility, or the ability to interpret complex and plentiful data--in other words, critical thinking--been so important to successful performance in the workplace.

At the same time as the cluster of information literacy skills has been repositioning as a generic graduate outcome, then, the skills base has been broadening. This movement and growth has occurred in response to the exponential increase in both the number of information channels that can be accessed, and the amount of information that flows through them. All members of the information society--particularly graduates--need to be able to navigate these channels.

That this information flood has been caused by mass communication through technology, in particular computers, is undisputed. Paradoxically, control of that information flood can be assisted by utilising another capability of those same computers--information systems. However, the most significant, versatile, transportable and accessible tool for the control of information is information literacy. Information literacy is not system-dependent; it can 'migrate' from platform to platform; it is backwards-compatible. It works equally well with online databases, paper-based archives, mass media and oral communication.

Information literacy is underpinned by sound critical thinking skills. In the 'information society', with environmental complexity perhaps the only constant in any decision-making equation, the broad range of subjects students need to master necessitates more than ever the teaching of thinking strategies which can be used to make sense of them.

Critical thinking is often discussed in the context of problem-solving, but needs to be distinguished clearly from the problem-solving process. Whereas the goal of critical thinking is to arrive at a judgment, problem-solving is a process, which comprises many decision points at which judgments must be made. The effectiveness of this process hinges on the quality of the critical thinking strategies and skills that have been brought to bear on the issues pertaining to the problem. Beyer, (3) for example, believes that critical thinking 'begins with a previous claim, conclusion or product and considers the question, "Of what truth or worth is it?"'. The ability to reach a sound judgment as to the significance of an idea or other information, whether it presents in the form of a scholarly article, an argument propounded by a politician, a problem of bio-ethics, or a financial markets crisis, is fundamental to the development of information literacy, as sound judgment underpins decisions made in any problem-solving process, and the achievement of optimal problem-solving outcomes is arguably one of the primary applications of information literacy.

Two taxonomies of skills provide useful frameworks for the conceptualisation of critical thinking; they are Beyer's classification, and Bloom's (4) taxonomy for the teaching of thinking skills in the cognitive domain.

Beyer's classification provides a framework for developing an understanding of the various components of thinking. Beyer describes three key components, all of which have to be present for clear thinking to occur: cognitive (thinking) operations; domain knowledge; and attitude. Domain-specific knowledge is the body of knowledge that a student acquires when studying, for example, psychology, law or ancient history. Attitudes important to the development of sound thinking skills, Beyer suggests, include respect for evidence, and a healthy scepticism and curiosity. Cognitive operations include three over-arching strategies: conceptualising, problem-solving, and decision-making. These strategies are underpinned by critical thinking skills such as detecting bias and fallacious arguments; distinguishing fact from opinion; and determining relevance. Finally, 'micro' skills, which fall into two groups: basic information processing such as recall, interpretation, synthesis and evaluation; and reasoning skills--the ability to formulate deductive and inductive arguments--are described.

Bloom's taxonomy of critical thinking skills is similar to the basic information processing 'micro skills' discussed by Beyer, but is more detailed. Bloom's taxonomy is represented in an hierarchical manner, from basic thinking skills such as knowledge, comprehension, and application, through to the 'higher order' thinking skills of analysis, synthesis and evaluation. Knowledge requires recall or recognition of facts, procedures, rules or events. Comprehension requires reformulation, restatement, translation or interpretation of that knowledge. Application requires the use of information in a setting or context other than where it was learned. Analysis requires recognition of logical errors; comparison of components; and differentiation between components. Synthesis entails the production of something original; or perhaps the solution of an unfamiliar problem, or the combination of parts in an unfamiliar way. Finally, evaluation requires the formation of judgments about the worth or value of ideas, products, or procedures. In the author's view, this highest level of critical thinking, then, supports the goal of achieving sound judgment, which in turn underpins effective problem-solving, which, as stated earlier, is arguably one of the primary applications of information literacy.

Information Literacy in Higher Education

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 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'. (5) 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 go further, and assert that information literacy requires a range of critical thinking skills: the ability 'to sort, to discriminate, to select, and to analyse the array of messages that are presented'. (6) Peacock states explicitly that the aim of information literacy is 'to promote critical thinking, increase information competence and equip individuals for lifelong learning'. (7) Kuhlthau takes a wide view, describing information literacy as 'the ability to construct one's own meaning from an information-rich environment'. (8)

However widely or narrowly defined, information literacy has been much debated in recent literature as a generic outcome of higher education. (9) 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 where, how, and what, to teach, are the matters under discussion.

The Australian and New Zealand Information Literacy Framework (2004) (10) sets out in detail the standards suggested for information literacy in higher education. According to that taxonomy, literacy includes, inter alia, recognising the need for information; finding information effectively; evaluating information; managing information; constructing new concepts; and legal, cultural, social and ethical use of information.

It is important to note that one of the abilities that should be subsumed under any definition of information literacy is the ability to determine when electronic sources of information should be chosen, and when paper-based or other sources are more appropriate. Too often in general debate and discussion the term 'information literacy' is used only in the context of 'information technology'. Coupled with students' willingness to embrace technology with uncritical enthusiasm, this impression, if uncorrected, can result in students failing to recognise the range of information sources of which an information literate person should be aware. This theme has been discussed elsewhere. (11)

A Teaching Framework for Undergraduate Information Literacy

It is axiomatic that information is not useful unless it can be retrieved. A student's ability to locate, analyse and articulate the value of information is fundamental to his or her academic success. These observations, made by the author in 1995 when tutoring a group of second-year undergraduates, many of whom seemed to be unable to conduct a simple search, were the genesis of several research projects that culminated in the completion of a PhD in 2002. (12) Two main questions seemed important: why couldn't students locate information, and how could their success be improved? Originally dealing only with the issue of information retrieval, the research, perhaps inevitably, led to the broader issue of information literacy.

Literature from two disciplines was reviewed as background to the research: cognitive psychology (information processing theory; learning theory; and developmental theory); and information retrieval (individual differences; models of information retrieval; concept-based teaching; course-integrated instruction). Arising from this theoretical background were four main 'prongs' of research: the development of a two-stage explanatory model of the information retrieval process (based on information processing theory); (13) a series of concept-based teaching modules (grounded in learning theory) testing the efficacy of that model in a large experimental study; (14) an analysis of the role of cognitive maturity in the information retrieval process (based on tenets of developmental theory); (15) and finally, the development of a framework for the teaching of broader aspects of information literacy, which framework drew together all theoretical aspects of the research. It is this final aspect of the research that is discussed below.

It is suggested that the relationship between information retrieval and information literacy is not purely hierarchical; that is, information retrieval skills are not subsumed under the wider concept of information literacy. Rather, there is an interaction between the two processes such that information retrieval draws necessarily on those aspects of information literacy--including critical thinking and analysis--that enable the process of retrieval to be effective. In terms of reasoning, critical thinking skills are in effect a 'sufficient cause' for successful information retrieval; that is, critical thinking must be present for successful retrieval to occur. An appropriate mental model (declarative knowledge representation) of the information need, and an understanding of the procedures required for query formulation (a problem-solving heuristic; procedural knowledge) are 'necessary causes'; that is, they may (and do) contribute to an effective search outcome. Critical thinking skills are the more important of the two clusters, however, as they underpin modification of declarative knowledge through the 'transforming' of the models as new knowledge is assimilated. With regard to the search process, the function of critical thinking is to support effective judgments, which in turn underpin decision-making throughout that iterative process. Again, as new information is gained, it is acted on by thinking skills, which in turn modify search procedures and strategies.

Figure 1 represents the author's understanding of the elements of information literacy, their inter-relationships, and the content and teaching strategies that are appropriate to the development of each element.

For any given information need, information literacy comprises the ability to locate, analyse and articulate the significance of materials pertinent to that need. Each of these three elements is represented in Figure 1 as a separate component. All elements must be present for an individual to be termed 'information literate', as the dotted lines on the diagram indicate. For example, an undergraduate who can perform two stages of the information retrieval process--interpreting the question successfully, and formulating suitable search strategies--is not necessarily going to locate appropriate literature--because the second element of literacy--analysing--must also take place, to establish the credibility of a source relative to information requirements, and actual relevance of citations to the search problem.

These skills in analysis are then used in the communication of the information located to the particular audience. The interaction between the three elements is represented by the double-headed arrows linking them.

This framework for the understanding of information literacy provides a useful starting point for the development of curricula designed to foster information literacy in undergraduates. The author suggests that the framework could work equally as effectively at any learning level, provided that the skills taught were adapted to the age and developmental level of the students being taught.

In Figure 2 (below), subject content that develops each of the three main elements of information literacy is listed. Teaching strategies grounded in learning theory: use of analogy; concept development; modelling; scaffolding; are used as appropriate when teaching each element. Further, end-user computing techniques (for example, use of online databases; data manipulation using spreadsheets) to support the development of information literacy are also incorporated into course content as necessary.

With regard to locating information, (Figure 2, element 1) teaching strategies developed for this research were effective in improving subjects' performance at both stages of the information retrieval process: question interpretation, and search strategy formulation. A problem-solving heuristic; modelling; concept-based teaching; use of analogy; anchoring new material to existing knowledge; all of these methods were useful in the development of information retrieval concepts and skills. Content covered in the teaching of successful information location included the use of the two-stage information retrieval model: analysing a search question, and conducting a search using a problem-solving heuristic.

End-user computing instruction included hands-on running of trial searches on University of Canberra online databases, and the internet.

Without skills in critical thinking, however, analysis of information located (Figure 2, element 2) for relevance and credibility cannot be assumed to occur. The second major area of instruction in information literacy therefore becomes critical thinking, including for example, the introduction of a framework to represent the relationship between thinking processes, domain knowledge, and attitude; followed by a framework that develops an understanding of the various thinking processes. The taxonomy developed by Beyer16 has proved useful to the author's teaching in this regard. Students readily grasp the hierarchical structure of thinking strategies (problem-solving, conceptualising and decision-making); underpinned by critical thinking skills (detecting bias; fact/inference confusion; fallacious arguments); and finally, types of reasoning: deductive and inductive.

At this point, introducing an analogy, such as a staircase, to explain a taxonomy of thinking skills (17) is effective. Using examples throughout to assist the grasping of the differences between these thinking skills--knowledge, comprehension, application, analysis, synthesis and evaluation--has proved useful to the author in explaining these concepts to students. Many students have remarked that this explanation of critical thinking skills has been of great assistance to them not only in information retrieval, but in preparing a wide range of assignments for university.

Critical thinking skills are essential to all stages of information literacy, not just the analysis stage. For example, the thinking strategy of conceptualising is drawn on in the first stage of information retrieval (question interpretation), and problem-solving and decision-making are utilised in the second stage (search strategy formulation). (18)

End-user computing that supports the development of element 2 competencies include the use of spreadsheets and databases for data input, manipulation, interpretation, and decision support.

The final element of information literacy in the model under discussion is articulating the significance of information located (Figure 2, element 3). Again, critical thinking skills are essential. Although articulating the significance of information was beyond the purview of the current study, the author has investigated links between critical thinking and written and oral communication in another study, in which results indicated, inter alia, that the teaching of thinking skills favourably influenced second-year undergraduate scores on oral and written literature reviews. (19)

When information is to be conveyed to an audience, the needs of the audience must be analysed; a decision must be made as to the appropriate communication channel (for example, written report, or oral presentation). Frequently, the same information must be adapted to the needs of a number of different audiences, for example, a presentation to peers, followed by a more formal written paper for a tutor. Skills such as establishing the main purpose of the information to be communicated: to inform or to persuade; to underpin decision-making; to develop an argument; language choice; writing style and tone; all of these communication skills are subsumed in the wider structure of information literacy.

End-user computing skills that support this stage of information literacy development include the use of computers for communication and presentation purposes: email; wordprocessing; and presentation packages such as powerpoint.

Providing students with an overview of information literacy as set out in Figure 2 above at the start of any first-year undergraduate program is likely to enhance significantly their understanding of many of the academic requirements that will be encountered during their studies. For example, providing students with definitions and examples of the difference between 'discuss' and 'analyse' will assist them to avoid fundamental errors in the level of sophistication of written papers often reported by tutors and lecturers, particularly when marking first-year papers.

Such a program, of course, is not a guarantee of information literacy by the end of undergraduate studies; rather, it is one means by which the development of literacy may be encouraged. Results from other aspects of this research suggested, for example, that the ability of some students to grasp hypothetical constructs, to determine relevance, to reason by analogy, or to solve problems containing multiple 'vectors', is influenced by their level of cognitive maturity. (20) Cognitive maturation, in turn, may be encouraged through the utilisation of teaching strategies grounded in learning theory. Indeed, regardless of possible level of cognitive maturity, results suggested that between 50% and 80% of undergraduates tested could not solve problems requiring the use of analogy, or containing multiple vectors, even when these problems were presented in everyday scenarios.

It follows that if not all undergraduates can reason by analogy, and determine relevance, then not all graduates will be able to deliver immediately the creative problem-solving capabilities that are today sought so keenly by employers in our competitive, frenetically-paced information society.

The author notes that the framework set out in Figure 2 aligns with the standards and outcomes described in the Australian and New Zealand Information Literacy Framework for higher education. In particular, element 1, locating, in the author's framework aligns with standards 1 and 2 (recognising the need for information; finding information effectively and efficiently). Element 2, analysing, aligns with standards 3 and 4 (evaluating information and its sources critically; managing information); element 3, articulating, aligns with standard 5 (constructing new concepts). Standard 6 relates to broader issues of the ethical, legal, social and cultural use of information and is beyond the purview of the Framework discussed in this paper.

Empirical Validation of the Framework

Teaching strategies discussed in the framework were developed deductively, after an extensive review of literature. These strategies were incorporated into teaching each element of the framework: locating, analysing, and articulating. Support for the efficacy of the framework was determined through experimental research, which is summarised below.

Locating

Teaching strategies grounded in learning theory were tested empirically in a large experimental study that followed a pre-test/post-test experimental design, using a sample of 254 undergraduate first year students at the University of Canberra. 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.

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 (administered in week 1 of first semester to first-year undergraduates in a unit teaching basic technology literacy) gathered baseline information on variables thought to be involved in information retrieval, such as level of education, age, gender, and computer anxiety; levels of knowledge of electronic database searching, problem-solving, and to a limited extent, cognitive maturity. These intervening 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.

Dependent variables were performance on the two post-tests. Survey 2 (post-test 1) measured electronic database knowledge, and was administered two weeks after the experimental module, which was taught in week two tutorials. The information retrieval assignment (post-test 2) was distributed to all subjects in week two. Completed assignments were submitted in tutorials in week four. The assignment required subjects to locate citations for articles 'highly relevant' to each of three search topics. These topics were of varying difficulty; topic three was the most difficult.

Items rated on the information retrieval assignment included, for search strategy: 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; self-evaluation of search success.

For evaluating search success, items rated included: relevance (inadequate, marginally adequate, adequate, good, superior); source (same rating); and overall search success (same rating).

The independent variable was the experimental 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 module was delivered in week two 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. (21) 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. Searches were conducted by subjects. 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 the unit's teaching aims. Of the 254 subjects, 199 (78%) submitted assignments--a good response rate. 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 with electronic database searching.

Statistical analysis suggested that there was no difference between experimental and control groups on electronic database knowledge on the pretest, and that therefore the two groups were equivalent before administration of the experimental treatment. Results on the first post-test (Survey 2) indicated a significant difference in favour of the experimental group ($p = .0018$). Overall, the experimental group performed 7.9% better than the control group on the post-test measuring electronic database knowledge. As intervening variables were controlled, these results supported the conclusion that the module was useful in improving subjects' electronic database knowledge.

Significant results were also found on a number of variables regarding differences between treatment groups in favour of the experimental treatment as measured by the information retrieval assignment (post-test 2). These significant results are summarised in Table 1 below.

Of 12 variables examined, Number of concepts (appropriate or inappropriate) was the only one that showed a significant difference between experimental and control groups for all three search topics. However, that variable was an important one, as previous research (22) had suggested that failure to identify appropriate concepts is one of the main reasons for search inadequacy.

In addition to these significant differences, results indicated that experimental treatment means were higher than control treatment means on 16 of the 21 variables measured by frequency of occurrence.

Finally, and most importantly, what was also apparent from these results is that information retrieval, to be successful, requires not only the 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, involving evaluation of sources for credibility and relevance.

In 1999 the author conducted Phase 2 of this study, in which teaching modules grounded in learning theory were again developed. In this second phase, subjects were 70 second-year undergraduates. The same experimental design was utilised; additional teaching modules addressed the development of critical thinking skills in the context of information retrieval, in order to determine whether experimental group subjects 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 did the control treatment group.

Analysis indicated 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 ($p = .002$).

Phase 1 results suggested that the concept-based approach to teaching information retrieval influenced search strategy formulation, search execution, and subject self-perception of search success. Phase 2 results suggested further that if wider aspects of information literacy--such as critical thinking--are taught, search success also improves.

Analysing and Articulating

The critical thinking module used in Phase 2 of the experimental study discussed above has also been tested for its efficacy in information analysis, and articulation of relevance (student assignments--literature reviews). (23) In both oral and written literature reviews, students who received the critical thinking module performed statistically better on analysis and communication of relevance (articulation) tasks than students who did not receive the module. Further, those students who received the module achieved learning outcomes faster than those who did not receive the module.

Conclusion

As little as ten years ago, information retrieval was regarded as the domain of the expert search intermediary. Technology, however, has brought information to the end-user, and it is for this large group, characterised by a broad range of individual differences and variability in performance, that teaching strategies need to be designed. Today, information is a commodity; it has value, and can be used for strategic purposes. In this context, information literacy is an essential competency to enable students, as future professionals, to function as lifelong learners in the information society.

It is usual for universities in Australia and elsewhere, to develop comprehensive statements as to the generic attributes they expect all students to have acquired on graduation. Such frameworks typically include competencies such as critical thinking, problem-solving, the ability to work in teams, and ethical, professional behaviour. In recent years, universities have been modifying these statements to include, in one form or another, information literacy. The Queensland University of Technology Library, for example, has developed an information literacy statement to support the generic attributes agenda of that university: 'The library's ultimate goal is to promote information literacy as a key competency for lifelong learning'. (24) The University of Canberra has reviewed its Generic Attributes for Graduates to reflect current thinking on information literacy as a crucial outcome of higher education. (25)

Not only is it important to include information literacy as a generic attribute for any university, it is also important that these frameworks distinguish clearly between information literacy, and information technology literacy. The author suggests that these two areas of student competence, whilst related in some of their applications, are nevertheless quite distinct. This difference can be clarified by the adoption and use of appropriate terminology to describe the separate competencies.

For example, language used to describe, and to distinguish, various aspects of computing and technology is evolving. The general term 'information technology' skills, in wide use in public debate, does not reflect the types of skills that universities are attempting to describe when discussing generic attributes of students in this regard. The term 'end-user computing' is a more accurate a descriptor of the competencies we would expect of all graduates, and enables a useful distinction to be made from those skills of a technical (and course-specific) nature, such as programming. Further, when taught as 'end-user computing', information technology is put into context, and is able to be understood and appreciated for what it is--a productivity tool for professionals.

The development of information literacy imperatives, and end-user computing requirements, has created new areas for the application of critical thinking skills. The inter-dependence of these three generic competencies yields a conceptual framework around which instruction can be shaped to good effect. The recognition of the importance of the inter-relatedness of these competencies is central to determining what, and how, students learn.

Of course, as with any other discipline, some students will learn on their own. The majority, however, need to be taught. The findings of the current study suggest teaching methods grounded in learning theory (modelling, analogy, scaffolding), that facilitate the development of aspects of information literacy, critical thinking and end-user computing. These methods appear to have real benefits for introductory knowledge acquisition in an undergraduate population characterised by a pedagogically difficult fusion of large individual differences, and a disinclination to seek instruction in the search process (possibly the result of a lack of understanding of the inherent complexity of the task).

When information literacy, critical thinking and end-user computing are viewed as parts of a whole, the issue is not one of 'training', but of education; the aim is not to teach 'skills', but to develop theoretical frameworks for '21st century literacy' (26) essential for any graduate to possess. In other words, the issue becomes one for a university to address, explicitly, in its course offerings.

As Candy (27) observed, Australian universities have an important role in developing 'knowledge workers' who possess 'those attributes--both generic and discipline-specific--which employers and the professions increasingly claim they expect of graduates'.

All of these concerns can be addressed if information literacy, critical thinking, and end-user computing are taught to first year undergraduates.

Information literacy is necessary not just for successful university study; it is essential to survival in the information age. Medical practitioners, educators, politicians, architects; professionals of every type need the knowledge and skills to be able to make sense of the information environment. 'Information overload' is a frequently reported problem within that environment. Even though computer information management systems are able to do some of the sifting, sorting and classifying work that enables information overload to be reduced, they are still only productivity tools.

The key to the cipher of information is information literacy: it is not system-dependent; it is backwards compatible; it is easily transportable and does not suffer system glitches and downtime. Our students need to be taught, with the best methods we are able to use, how to exploit the potential of that most powerful of sense-making instruments--the human mind.

Table 1
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

Notes

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(2) This paper is an abridged version of one aspect of the author's PhD thesis The Development of Enhanced Information Retrieval Strategies in Undergraduates through the Application of Learning Theory: an Experimental Study, submitted to the University of Canberra in 2002. The thesis is available through the University of Canberra Library.

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(15) K Macpherson 'Problem-Solving Ability and Cognitive Maturity in Undergraduate Students' Assessment & Evaluation in Higher Education vol 27 no 1 2002 pp5-22

(16) Beyer Practical Strategies

(17) Bloom Human Characteristics

(18) Macpherson 'An Information Processing Model'

(19) K Macpherson 'The Development of Critical Thinking Skills in Undergraduate Supervisory Management Units: Efficacy of Student Peer Assessment' Assessment & Evaluation in Higher Education vol 24 no 3 1999 pp273-284

(20) Macpherson 'Problem-Solving Ability'

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(22) A Spink 'Term Relevance Feedback and Mediated Database Searching: Implications for Information Retrieval Practice and Systems Design' Information Processing & Management vol 31 no 2 1995 pp161-171; F Lancaster et al 'Searching Databases on CDROM: Comparison of the Results of End User Searching' RQ vol 33 no 3 1994 pp370-386

(23) Macpherson 'Development of Critical Thinking Skills'

(24) Peacock 'Teaching Skills' p34

(25) University of Canberra Generic Skills and Attributes of University of Canberra Graduates from Undergraduate and Postgraduate Coursework Courses 2002

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