THE DEVELOPMENT OF ENHANCED INFORMATION RETRIEVAL STRATEGIES IN UNDERGRADUATES THROUGH THE APPLICATION OF LEARNING THEORY: AN EXPERIMENTAL STUDY

by

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VOLUME I

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ABSTRACT

In this thesis, teaching and learning issues involved in end-user information retrieval from electronic databases are examined. A two-stage model of the information retrieval process, based on information processing theory, is proposed; and a framework for the teaching of information literacy is developed.

The efficacy of cognitive psychology as a theoretical framework that enhances the understanding of a number of information retrieval issues, is discussed. These issues include: teaching strategies that can assist the development of conceptual knowledge of the information retrieval process; individual differences affecting information retrieval performance, particularly problem-solving ability; and expert and novice differences in search performance.

The researcher investigated the impact of concept-based instruction on the development of information retrieval skills through the use of a two-stage experimental study conducted with undergraduates students at the University of Canberra, Australia. Phase 1 was conducted with 254 first-year undergraduates in 1997, with a 40 minute concept-based teaching module as the independent variable. A number of research questions were proposed:

1. Will type of instruction influence acquisition of knowledge of electronic database searching?
2. Will type of instruction influence information retrieval effectiveness?
3. Are problem-solving ability and information retrieval effectiveness related?
4. Are problem-solving ability and cognitive maturity related?
5. Are there any differences in the search behaviour of more effective and less effective searchers?

Subjects completed a pre-test which measured knowledge of electronic databases, and problem-solving ability; and a post-test that measured changes
in these abilities. Subjects in the experimental treatment were taught the 40
minute concept-based module, which incorporated teaching strategies
grounded in learning theory. The strategies included: the use of analogy;
modelling; and the introduction of complexity. The aims of the module were
to foster the development of a realistic concept of the information retrieval
process; and to provide a problem-solving heuristic to guide subjects in their
search strategy formulation. All subjects completed two post-tests: a survey
that measured knowledge of search terminology and strategies; and an
information retrieval assignment that measured effectiveness of search design
and execution.

Results suggested that using a concept-based approach is significantly more
effective than using a traditional, skills-demonstration approach in the
teaching of information retrieval. This effectiveness was both in terms of
increasing knowledge of the search process; and in terms of improving search
outcomes. Further, results suggested that search strategy formulation is
significantly correlated with electronic database knowledge, and problem-
solving ability; and that problem-solving ability and level of cognitive
maturity may be related.

Results supported the two-stage model of the information retrieval process
suggested by the researcher as one possible construct of the thinking
processes underlying information retrieval.

These findings led to the implementation of Phase 2 of the research in 1999.
Subjects were 68 second-year undergraduate students at the University of
Canberra. In this Phase, concept-based teaching techniques were used to
develop four modules covering a range of information literacy skills,
including: critical thinking; information retrieval strategies; evaluation of
sources; and determining relevance of articles. Results confirmed that subjects
taught by methods based on learning theory paradigms (the experimental
treatment group), were better able to design effective searches than subjects
who did not receive such instruction (the control treatment group). Further,
results suggested that these teaching methods encouraged experimental group subjects to locate material from more credible sources than did control group subjects.

These findings are of particular significance, given the increasing use of the unregulated internet environment as an information source.

Taking into account literature reviewed, and the results of Phases 1 and 2, a model of the information retrieval process is proposed.

Finally, recognising the central importance of the acquisition of information literacy to student success at university, and to productive membership of the information society, a detailed framework for the teaching of information literacy in higher education is suggested.
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I would like to dedicate this thesis to my beautiful daughters, Alex and Kath – with the gratuitous advice – never, ever, give up!
1. INTRODUCTION

1.1 Purpose of the Study

It is axiomatic that information is not useful unless it can be retrieved. Many information retrieval mechanisms available today are computer-based; but is the ability to exploit their potential contingent only on skills training in the mechanics of their operation?

Literature reviewed in this thesis suggested that successful database searching in undergraduates is contingent on a combination of technical skills, and information retrieval conceptual knowledge. Although a number of studies have suggested the efficacy of including conceptual information as well as technical skills in information retrieval instruction, questions for further research have been raised. Two of these questions are: the teaching approach that might best facilitate student learning of concepts of information retrieval; and the actual content of such courses.

Further, the literature suggested several models and alternative conceptualisations of the information retrieval process. These models have been constructed using various theoretical frames; all have value in informing our understanding of the mechanisms of the information retrieval process. Although some of these models have drawn on the tenets of cognitive psychology to explain the search process, none of the models surveyed combined elements of the three major branches of cognitive psychology: information processing; learning theory; and developmental theory, to represent the search process, or to suggest possible teaching and learning strategies to develop knowledge of such a process.
The purpose of this research then, was twofold: firstly, to develop a model of the information retrieval process that might contribute to an overall understanding of the thinking processes underpinning a search, and from this, secondly; to design and test empirically the efficacy of an instructional approach suggested by such a model.

The experimental study constructed to achieve these goals was in two phases. Phase 1 tested the efficacy of a single teaching module based on learning theory paradigms to influence the acquisition of search knowledge and skills. Phase 2 comprised a series of four teaching modules based on the same paradigms, designed to develop not only a knowledge of the search process and skills, but also thinking skills to facilitate the ability to judge relevance and credibility of retrieved items.

A second, over-arching, theoretical model emerged from this study: a framework for the teaching of information literacy.

In this chapter, aspects of the study will be introduced. Section 1.2 provides a background to the study. Section 1.3 introduces the field of human factors - individual differences - that impact on information retrieval performance. Section 1.4 provides definitions of terms as they are used in this thesis.

Following these introductory sections, in Chapter 2, the significance of the study is discussed. Literature relating to information retrieval is reviewed in Chapter 3. Theories from the discipline of cognitive psychology relevant to information retrieval are discussed in Chapter 4. In Chapter 5, the theoretical framework central to this study is described, and hypotheses for Phase 1 are set out.
Chapter 6 details method for Phase 1. Results for that Phase are reported in Chapter 7. A discussion of these results may be found in Chapter 8.

Phase 2 is dealt with in Volume II of this thesis, and comprises Chapter 9 (Method); and Chapter 10 (Results). In Chapter 11, results for Phases 1 and 2 are summarised. In Chapter 12, conclusions drawn from the entire study are discussed; a model of information retrieval proposed; and a framework for the teaching of information literacy suggested.

1.2 Background to the Study

The starting point for this research was observation by the researcher in 1994 and 1995 of the mixed success of some undergraduate students at the University of Canberra in identifying and retrieving relevant information from the University's CD-ROM databases for completion of assignments. These observations suggested that frequently, students were unable to identify and obtain appropriate journal literature, even though they had completed University of Canberra library tutorials on CD-ROM operation. Further, students commonly were unable to determine the relevance, effectively summarise, critically evaluate, or articulate the significance of the literature they did locate. Observation by the researcher indicated further that instruction in how to analyse questions would in general improve students' ability to perform these tasks.

The researcher concluded that in order to be able to articulate a question, students needed to be able to think hypothetically, and to possess good problem-solving skills. In order to evaluate sources, analyse questions and articles, and synthesise search results, they needed well-developed critical thinking skills.
Further, the student population is characterised by a wide range of individual differences that influence the ability to search effectively, such as logical thinking, problem-solving ability, computer experience, knowledge of synonyms, and procedural knowledge.

The researcher hypothesised that if students were given concept-based instruction in the information retrieval process, and instruction in problem-solving skills, performance on information retrieval tasks could be enhanced.

The research reported in this thesis examines a number of issues involved with this information retrieval process. Firstly, individual differences affecting information retrieval performance, particularly, problem-solving ability, are investigated. A number of measures of search effectiveness, such as search strategy formulation, recall, and precision, are discussed. Secondly, the relationship between cognitive maturity, problem-solving ability and successful search outcomes is examined. Finally, the efficacy of cognitive psychology as a discipline that provides explanations for a number of important elements in the information retrieval process, is discussed.

Cognitive psychology is of value in the information retrieval context for three reasons:

1. Information processing theory allows an understanding of the way knowledge is stored in human memory, and the way experts and novices differ in their performance on information retrieval tasks.
2. Cognitive learning theory provides a number of strategies that can be used to teach conceptual knowledge of the information retrieval process.

3. Cognitive developmental psychology provides a possible explanation as to why individual differences in thinking maturity may influence information retrieval effectiveness.

Issues in cognitive psychology are discussed in Chapter 4. In the next section, definitions of terms used in this thesis are provided.

1.3 Definitions

In order to facilitate clarity of meaning, the following definitions of terms used in this thesis are provided.

*Bibliographic instruction*: the teaching of skills to enable location of information from a broad range of sources, including paper-based, CD-ROM, and online media. These skills are usually, but not always, taught in libraries.

*Concept-based instruction*: teaching strategies, grounded in learning theory, that encourage the acquisition of knowledge of the information retrieval process.

*Course-integrated instruction*: bibliographic instruction that is linked to a particular subject; for example, teaching information retrieval skills as part of a first-year science subject, at a time when a research assignment needs to be completed for that subject.
*Domain knowledge:* knowledge that is particular to a specific discipline, or domain, of study; for example: medicine; chemistry; ancient history; English literature. An expert in a field possesses more domain knowledge than does a novice.

*Electronic database:* a CD-ROM or online index.

*End-user:* any person who seeks to obtain information from electronic databases, and who is not an expert search intermediary (for example, an undergraduate).

*Expert search intermediary:* librarians or other persons who have received extensive training on, and have considerable experience with, information retrieval from electronic databases.


*Information literacy:* the ability to “recognize when information is needed and to locate, evaluate, effectively use, and communicate information in its various formats” (State University of New York Council of Library Directors, 1997, Online, in Spitzer, Eisenberg & Lowe, 1998:24). Further, information literacy requires critical thinking skills: the ability “to sort, to discriminate, to select, and to analyze the array of messages that are presented” (Lenox & Walter, 1992 in Spitzer, Eisenberg & Lowe, 1998:26).
Information retrieval: “a process in which sets of records or documents are searched to find items which may help to satisfy the information need or interest of an individual or group” (Tague-Sutcliffe, 1996:1).

Learning theory: a body of knowledge on how people learn, that takes into account the nature of the learner, the nature of the knowledge to be learned, and the nature of the process by which the learner obtained the knowledge required (Piette, 1995 in Martin, ed, 1995). Discussion of learning theory is often accompanied in the literature by teaching methodologies that flow from those theories.

Problem: a problem exists “when a living organism has a goal, but does not know how this goal is to be reached” (Duncker, 1945 in Garnham & Oakhill, 1994:200).

Problem solving: “thinking that is directed toward the solving of a specific problem that involves both the formation of responses and the selection among possible responses” (Solso, 1995:440). Problem solving involves a problem space, which comprises an initial state, a goal state, and some kind of route, or series of processes, to get from the beginning, to the goal, problem state (Newell & Simon, 1972 in Anderson, 1985).

Problem-solving heuristic: in information retrieval, a means to negotiate the problem space.

Reformulation: the recasting of a search strategy, using different combinations of concepts and synonyms, joined by Boolean operators.

Search formulation: see “search strategy”.
Search history: a record of search strategies enabling identification of reformulations including concepts, synonyms, Boolean operators, and truncation.

Search strategy: the combination of identified concepts and synonyms using Boolean operators, and possibly truncation, to enable a computer to run a search, for example "Australia* AND society AND (internet OR web)".

Skills-based instruction: information retrieval instruction that concentrates on the teaching of technical details and procedures relating to the mechanics of a particular operation, for example: instruction in the procedure (which buttons to "click" on) to enable the printing of a record of search history. Skills-based instruction focuses on how to do something, rather than on why it is being done.

In this chapter, the purpose and background of the study have been outlined, and terms defined. In the next chapter, the significance of the study is discussed.
2. SIGNIFICANCE OF THE STUDY

2.1 Introduction

A focus in teaching and learning at the University of Canberra 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 (Candy, 2000; Bruce, 2000a,b, 1998; Bundy, 1999; Yerbury & Parker, 1998; Julien, 1998; Halpern, 1998). A second focus at the University is the process of learning; for example, what teaching strategies will result in optimal learning outcomes?

In this study, the researcher tested the efficacy of concept-based teaching strategies to achieve learning outcomes in information retrieval superior to those achieved by more widely used skills-based approaches.

Results of this study are of significance in two areas. Firstly, information literacy: in particular, information retrieval. A student's ability to retrieve information is fundamental to his or her academic success. The results of this research suggest that concept-based teaching can lead to more students being able successfully to locate and evaluate research material for university assignments.

Secondly, results are of significance to teaching and learning in higher education generally. The theories underpinning the teaching strategies developed for this study may be able to be adapted to suit a variety of teaching situations. In other words, the approaches underpinning the teaching strategies may be transferable to other teaching situations and to other subjects, even though the learning outcomes are not. The researcher notes, for example, that general problem-solving strategies taught in the context of one subject, usually are not transferable to another subject, or domain of knowledge (Perfetto, Bransford & Franks, 1983 in Komatsu, ed. 1994).
Further, problem-solving strategies are most effective when they are domain-specific; that is, when they are tailored to the specific requirements of the problem area (Gagne, Yekovich & Yekovich, 1993). This means that the teaching strategies that may lead to the successful adoption of a problem-solving strategy for information retrieval could be used in other subjects, but the significance of the problem-solving strategy (ie, learning outcome) to another domain may not be recognised by students without that problem-solving strategy being taught in that second subject.

With regard to theory development in the area of information retrieval, this study contributes a new model of the process, that incorporates a number of features of existing models, and introduces several new features, in an attempt to explain the information retrieval process. Further, results of the study lend support to the efficacy of this model.

Phase 2 of the study, which was developed to test the importance of a set of critical thinking skills in the identification of credible and relevant research literature, leads into implications for the wider discipline of information literacy. The results of Phase 1 and 2 in combination gave rise to the development of an over-arching framework for the teaching of information literacy. This framework is able to be adapted to teaching and learning requirements of any age level, and further research applying such a model to any of these levels is suggested.

In the next section, the connection between Phase 1 of the study, focusing on information retrieval, and its link to Phase 2 of the study, dealing with a wider scope of capabilities subsumed by information literacy (of which information retrieval is one component), is discussed.
2.2 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.

Technology is both a primary cause of the information flood, as it makes information much more widely available; and a means of controlling it. Although the internet is the major river of information, other technology-based information channels - television and radio - contribute to the flow. Other tributaries are paper-based (although still enabled by technology), for example: commercial publishing, and business practices that ensure the inexpensive and extensive reproduction and dissemination of information...
through computer printers, desktop publishing and photocopiers in the office.

If the wellspring of the information flood is mass communication through technology - in particular - computers, paradoxically control of that 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 the information flow, 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. A perusal of recent higher education literature supports this view; Wind (1996), for example, stresses the need for business schools to focus on teaching critical thinking skills, to enable both effective evaluation of management literature, and to facilitate creative problem solving. McKenna & Williams (1997:35) also argue for a paradigm shift, commenting that “the goal of tertiary education should be to change students’ interpretations of their world by increasing their understanding of it”. Critical thinking skills are central to such a goal.

Further, Donald (1992:48) observes that “if we are to promote thinking in our students, our teaching strategies must reflect that intention”.

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 (1987:33), 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 (1987) classification, and Bloom's (1976) taxonomy for the teaching of thinking skills in the cognitive domain.

Beyer's (1987) 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 (1976) taxonomy of critical thinking skills is similar to the basic information processing “micro skills” discussed by Beyer (1987), 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 researcher’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.

2.3 Information Literacy in Higher Education
A comprehensive discussion of the elements of information literacy is provided by Spitzer, Eisenberg & Lowe (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, Online, in Spitzer et al, 1998:24), 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 & Walter (1992, in Spitzer et al, 1998:26) 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 (2001:27) 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, ed, 1999:7) 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 (Watson-Boone, 2000; Webber & Johnston, 2000; Bruce, 2000a,b, 1998, 1997; Bundy, 1999; Yerbury & Parker, 1998; Julien, 1998; Halpern, 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: where, how, and what, to teach, are the matters under discussion.

In a report commissioned by the Australian National Board of Employment, Education and Training: Developing Lifelong Learners though Undergraduate Education (Candy, Crebert & O’Leary, 1994), the centrality of information literacy in undergraduate education, and in enabling a philosophy of lifelong learning to be followed, was discussed. The Report described information
literacy as "fundamental" to the skills of graduates, and further that in our
information age, "mastery of all manner of electronic databases, indexes and
networks is essential" (Candy, Crebert & O'Leary, 1994:102). The authors
concluded that

it is important, therefore, that graduates leave
university equipped with the skills and strategies to
locate, access, retrieve, evaluate, manage and make
use of information in a variety of fields, rather than
with a finite body of knowledge that will soon be
outdated and irrelevant (Candy, Crebert & O'Leary,

In other words, Candy et al (1994) were of the view that transferable, critical
thinking and information management skills were of over-riding importance
in higher education. It is worth noting here that this definition does not
single out information technology as the only domain in which information
literacy functions. In fact, 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'
williness 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.

More recently, Candy (2000) discussed these themes in the context of the
need for graduates to be able to function as "knowledge workers". Candy
quoted results of a study by Starbuck (1992, in Candy, 2000:269) to the effect
that "knowledge workers" in today's "information society" - in the case of
the Starbuck study: a policy-oriented think-tank, a firm of business
consultants, and a firm of research lawyers - "gather information through
interviews or reading; they analyse and interpret this information; and they make written and oral reports to clients and colleagues”. In other words, generic information literacy skills, including critical thinking skills such as analysis and interpretation, underpin professional practice, irrespective of discipline.

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 Research Librarians, 2001). These Standards are discussed in Chapter 12 of this thesis.

With regard to determining what aspects of information literacy should be taught in higher education, Julien (1998) conducted an empirical study surveying 40 professional-level librarians teaching in academic libraries in New Zealand, in order to investigate librarians’ views on the shift from an emphasis on what she described as bibliographic instruction and user education, to information literacy. Regarding a definition of information literacy, all respondents believed that information literacy included “understanding how to locate efficiently and effectively information from many sources”; 97.5% believed that understanding how to use this information was important; 92.5% believed “understanding how to analyse and evaluate information critically” was important, and 87.5% thought “understanding that there exists a wide variety of information sources beyond the obvious” was important (Julien, 1998:309). That is, this survey of experts revealed a high consensus on the elements comprising information literacy: locating information; understanding how to use it; critically evaluating it; and appreciating the range of sources available.

With regard to what should be taught, respondents in that study were asked to rank objectives for the teaching of information literacy. “How to find information in various sources” was ranked the highest overall; followed by
"locating materials in library"; "general research strategies"; "how to evaluate the quality and usefulness of information critically"; and "how databases in general are structured". However, fewer than half (42.5%) of the respondents reported that they actually set written objectives for their user education programs, and evaluation of these programs was generally informal. Julien conducted a similar survey in Canadian libraries with a sample of 164 librarians. The survey indicated that only 7.9% of the respondents had written objectives for their user education. Julien argued that as setting written objectives tends to reflect the quality of teaching, and given that few of the respondents actually set such objectives, it was unlikely that in either Canada or New Zealand that the respondents' stated interest in the need to develop information literacy in students in reality was being met.

In this chapter, the development of information literacy as an essential outcome of higher education, and the role of critical thinking to the achievement of that outcome, have been discussed. Literature relating to these issues has been canvassed. In the next chapter, literature relating to a range of issues in information retrieval is reviewed.
3. LITERATURE REVIEW - INFORMATION RETRIEVAL

In the previous chapters, the genesis, aims, background and significance of this study were described. In this chapter, literature pertinent to information retrieval is reviewed. Section 3.1 canvasses a range of issues involved with, and characteristics of, information retrieval. In section 3.2, models that represent the retrieval process are described. In section 3.3, teaching and learning approaches to information retrieval are discussed. Section 3.4 discusses methodologies employed in research into information retrieval. Section 3.5 provides a conclusion that draws together the various elements discussed in this chapter, and describes the scope for research that is implied by their combination.

It is noted at this point that terminology is by no means precise when discussing issues of information retrieval. Key researchers in the area use different terms to describe the search process. Marchionini (1995) for example, provides an excellent argument for using the phrase “information seeking” rather than “information retrieving” when discussing the search process. In his view “seeking connotes the process of acquiring knowledge; it is more problem oriented as the solution may or may not be found” (Marchionini, 1995:6).

Limberg (1999) also adopts this terminology. Others (for example, Bates, 1989; Kuhlthau, 1988), use the term “search process”; whilst Wilson (1998) discusses “search behaviour”. Spink (1997) discusses “information seeking and retrieving”. In this thesis, the term information retrieval will be used to describe “a process in which sets of records or documents are searched to find items which may help to satisfy the information need or interest of an individual or group” (Tague-Sutcliffe, 1996:1).

In the following section, issues relating to describing and characterising information retrieval, including: search strategies; naming search terms; logical
errors; expectations of novices; the nature of expert searching; and the role of individual differences; will be discussed.

3.1 Characterising Information Retrieval

"'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, Elzy, Zeter, Metzler & Low, 1994:382). Borgman, Moghdam & Corbett (1984:19) 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: end-users.

Even for the general population accessing the internet, this prediction has some validity. If one focuses on higher education and the students involved in that sector, the accuracy of the prediction is difficult to dispute; databases and other electronically available sources are now accessed routinely by an end-user population characterised by variable search expertise. In the next sub-section, issues relating to information retrieval, including the development of search strategies, the use and selection of search terms, and logical errors, will be discussed.

3.1.1 Search Strategies and Search Terms

Studies in information retrieval in the last 15 - 20 years have changed their focus as technology has evolved. In the early 1980s, studies focused on expert searching of online databases. Experts were usually defined as trained librarians, or search intermediaries whose occupation it was to conduct searches on behalf of the client, or end-user. When CD-ROM databases became
widely available, interest turned to search behaviours of individuals accessing these offline databases. Some studies compared searches done on both offline, and CD-ROM, databases (Nahl-Jakobovits & Tenopir, 1992). Finally, the variable most investigated became the "end-user" (Balaraman, 1991). The distinction between the various electronic media increasingly has become blurred in the last few years; current research focuses on information retrieval by end-users from electronic databases and the internet. The distinction between CD-ROM and online electronic database sources has become relatively unimportant, at least to novice end-users.

Search Strategies

Wildemuth, Jacob, Fullington, de Biek & Friedman (1991) discussed the iterative nature of search "moves", or strategies. They summarised some general approaches to the analysis of these search strategies, and noted that common errors in end-user searching include incorrect use of truncation, failure to use obvious synonyms, and incorrect use of Boolean logic. Lack of understanding of Boolean logic was also identified by Puttapithakporn (1990) as a problem. Wildemuth et al (1991) examined search strategies used by 26 medical students, and found that the number of search reformulations (that is, the number of combinations of search terms) is related to individual differences in the searching behaviours of students. Further, they found that differences in strategies are elicited by different problems, and that the average number of strategies per student decreased as students became more experienced.

Borgman (1986) classed the problems encountered by end-users as being either procedural, or conceptual. The latter term refers to difficulties arising from not understanding how the system operates behind the screen; viz, the end-user's conceptual model of the computer system. Conceptual problems further differentiate into: retrieval difficulties, such as use of Boolean operators; and vocabulary problems in matching the system's language. These problems also involve the end-user's inability to express his or her information need.
Wallace (1993) suggested that end-user training be at the time when there is an immediate need to know, for example, when an assignment is being researched; and that what is required for success is for the end-user to be taught “a process or plan of action” (Wallace, 1993:251) to enable confidence in a successful search outcome to be engendered. Wallace (1993) found that two-thirds of searches produced 10 or fewer results; 82.1% of searches produced 25 or fewer results, well within the range that end-users in other studies were willing to investigate. Wallace conducted a transaction log analysis at the University of Colorado using logs from 11 terminals over 20 hours of undergraduate search time. These logs recorded time of input, and search strategy used on the CARL databases. In all, 4,134 searches were analysed. Wallace found that searchers often are unable to think of alternate search terms or strategies when their initial attempts fail; that is, they had difficulty reformulating searches. Further, she found that common search problems include variant spellings and synonyms.

Lancaster, Elzy, Zeter et al (1994) found that end-users of CD-ROMs (35 academic staff or graduate student subjects at Illinois State University) locate only about a third of the really important items when compared to a single librarian, or a team of librarians on the ERIC database. Lancaster et al found that the greatest problem faced by library patrons, even those represented in their study - academics and graduate students - is the fact that they do not identify and use all of the terms needed to perform a more complete search, because they search too literally. For example, one subject when searching for information on children aged four to eight years, used the terms “young children” and “early childhood education”, but not “primary education” and “preschool education” (Lancaster et al 1994:329).

Lancaster et al suggested that in order to improve end-user searching, some way of leading them from literal meanings to other terms more comprehensive,
needs to be incorporated in instruction. Further, they suggested (1994:383) that “it is not so much logical errors that produce poor searches as inadequate search strategies”. They suggested instruction that incorporates appropriate examples would be useful in improving search success.

Penhale & Taylor (1986) also 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 randomly assigned 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, 1986:213). This difference in recall was attributed by Penhale & 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, 1986:215).

**Naming or Labelling Search Terms**

The degree of agreement between searchers on naming or labelling of search terms is relatively low (Saracevic, 1991). Further, although the selection of search concepts and search terms is one of the most important phases of the search process, it is a task that is carried out very inconsistently on various occasions (Iivonen, 1995).

Iivonen’s research, and that of others (Collantes, 1995; Chen & Dhar, 1991; Erlich & Cash, 1994a; Lancaster et al, 1994), suggests that searchers do not necessarily interpret search requests differently, but use a great variety of terms to express those search requests in a search process. Furnas (1987 in Iivonen, 1995), observed that people use a surprisingly large variety of words
to refer to the same thing, and that in fact, no single access word, however well chosen, can be expected to cover more than a small proportion of end-users' attempts to access the same information. As Bates (1986:366) observed, "the individual searcher ... is usually unaware of the many terms that might be used." Spink (1995) recommended that end-users should be trained to identify additional search terms from retrieved items for query expansion, and to reflect their domain knowledge in the construction of a written question statement that can be utilised and modified as a source of search terms during their interaction with an information retrieval system.

An area of research related to issues in information retrieval, but beyond the scope of this discussion, is computer interface design. For a discussion of these issues, relevant sources include Sebillotte & Scapin, 1994; Coll, Coll & Nandavar, 1993; Davis & Bostrom, 1993; or Hyldegaard, 1993.

Summary
The problems of end-user searching that emerge from these studies include: firstly, that end-users are ignorant of search techniques. Secondly, identification of sufficient concepts to enable appropriate coverage of the search topic, together with the lack of consistency in "naming" of concepts, is a problem. Thirdly, common search errors are incorrect use of truncation, logical errors (Boolean operators), and failure to use obvious synonyms.

In the next sub-section, expectations of novice searchers will be discussed.

3.1.2 Expectations of Novice Searchers: Ignorance is Bliss
A number of researchers have discussed the gap between novice searcher understanding, and the reality of an effective search. Applegate (1993), for example, discussed the phenomenon of the "false positive"; that is, the fact that many end-users express happiness with the outcome of poorly-executed searches. Applegate suggested that end-user satisfaction should be determined by a combination of questions dealing with satisfaction in terms of search
questions answered (material satisfaction), and factors such as context and expectations. Applegate suggested that many surveys in which satisfaction with search results is explored, ask the question in much too simplistic a fashion. Consequently, results from such surveys are skewed toward an end-user who, whilst emotionally satisfied with search results, is, in fact, quite likely to have gathered less-than-optimal material.

With regard to a novice searcher's ability to understand the complexities involved with searching, Matthews (1983, in Borgman, 1986) found that end-users expected to spend no more than 30 minutes learning online searching, and most were unwilling to invest even this much time. These findings are supported by Hunter (1991), who observed that information seekers do not want to take the time to learn. On the other hand, librarians completed courses of up to 16 weeks in order to learn search techniques (Borgman, 1986).

As Oberman (1991:191) commented, "perceived end-user happiness, though a desirable by-product, is not acceptable from an instruction librarian's perspective ... end-users must understand the online environment" (italics added).

Littlejohn (1989 in Balaraman, 1991) and Barbuto & Cevallos (1991) found that end-users were "mostly satisfied" with search results. However, in the light of Applegate's findings on the "false positive" nature of end-user satisfaction with search results, these results should be interpreted with caution.

Bates (1986), and Nielsen & Baker (1987, in Dwyer, Gossen & Martin, 1991) also commented on the fact that there appears to be no close correlation between search efficiency and search satisfaction. Nielsen & Baker (1987, in Dwyer, Gossen & Martin, 1991) commented that the typical end-user may actually be very satisfied with a search, even though results are poor. The "typical" end-
user is not in a position to evaluate results in a thorough way, as they do not know how much of value has been missed (Hancock-Beaulieu, 1990).

Dalton & Dartnall (1994) observed that, while 89% of respondents to their survey described searches as useful, this may not imply that the searches were proficient.

A number of studies have reported that end-users (usually novice undergraduates) made comments of the "Wow! This is fantastic!" variety when using CD-ROMs (Lancaster et al, 1994), despite the fact that their searches were rated as inadequate by search experts. Such comments reflect the false positive phenomenon in action.

The term "novice" does not only apply to students. Siegfried, Bates & Wilde (1993) reported, for example, that in their study of online searching of 27 visiting humanities scholars at the Getty Center for the History of Art and the Humanities (California), more than 25% never used a Boolean "OR", despite participation in a one-day training program. Sixty-three per cent of their search terms were single-word terms. Cooper & Burchfield (1995) also observed that academic staff may suffer from problems in understanding information retrieval.

As to what comprises a comprehensive search, Barbuto & Cevallos (1991) found that 32.6% of end-users defined a comprehensive search as between one and 10 items; over 54% thought "comprehensive" meant between one and 20 items. Expert searchers, on the other hand, regard more than 50 items as comprehensive. Bates (1984) suggested that search intermediaries may sometimes adhere to the "fallacy" of a perfect 30 item online search, in which all search topics can be delineated effectively by that number of search items.
A number of researchers have commented on the fact that search skills need to be practiced regularly in order to build and maintain expertise. Many students are infrequent end-users and are therefore unable to build expertise; in fact, they remain "permanent novices" (Borgman, 1986:390).

**Summary**

Research concerning expectations of novice end-users points to several characteristics of this group that need to be considered in the design of any course of instruction aimed at this audience.

Firstly, whilst many end-users are emotionally satisfied with their searches, the actual content may not be very good (the "false positive" phenomenon).

Secondly, novice end-users are willing to spend little, if any, time learning how to search databases.

Thirdly, a novice end-user's definition of a "comprehensive" search encompasses significantly lower numbers of articles than does an expert searcher's definition.

Fourthly, most novice end-users do not access databases sufficiently often to move from novice to expert skills ("permanent novices").

These features in combination form a picture of today's "typical" undergraduate searcher as a person who lacks an understanding of the complexities of database searching.

It was observed centuries ago that, "The lowest form of thinking is the bare recognition of the object. The highest, the comprehensive intuition of the man who sees all things as part of a system" (Plato, in Solso, 1995:89). It is to the
nature of expert search behaviour, which is characterised by the ability to see the “big picture”, that the discussion will now turn.

3.1.3 The Nature of Expert Searching

According to Marchionini, Dwiggins, Katz & Xia (1993), information seeking is a problem-solving activity that is being undertaken increasingly by end-users. Full-text databases are being developed for those people with “low levels of information-seeking expertise” (Marchionini et al, 1993:36).

In a series of four studies, Marchionini et al investigated the differences between the search strategies of expert search intermediaries (for example, librarians) and domain experts (for example, in science or law) in order to ascertain any differences that might be of use in the teaching of end-user searching. Differences between groups were not significant; Marchionini et al found as many individual differences, as differences based on domain expertise. In qualitative terms, they found that domain experts used searches based on knowledge of content, and that search experts used their problem-solving expertise in order to find information. However, Marchionini et al noted that small sample sizes, the fact that the domain experts had considerable search experience, and that the search intermediaries had considerable domain knowledge, probably blurred differences between groups.

Suchman (1987, in Marchionini et al 1993:37) described expertise as “the application of knowledge and experience to differentiate between relevant and irrelevant information”. Further, experts perceive large meaningful patterns in their own domains (Leshgold et al, 1988 in Marchionini et al, 1993) which reflect the organisation of a knowledge base rather than superior perceptual skills (Glaser, 1987 in Marchionini, 1993). These ideas are discussed more fully in Chapter 4 of this thesis. Marchionini et al (1993:38) commented that information seeking is a fundamental cognitive activity which has increased in
importance in "today's information-intensive world". They described information seeking as comprising a series of subprocesses: recognition of a problem; definition; choice of search system; query formulation; query execution; examination of results; evaluation of relevance; and further query formulations. They concluded that domain and search expertise are not independent, but in general, that domain experts are content-driven, whereas search experts are problem-driven. Novice-expert differences in the context of cognitive psychology are discussed in Chapter 4.

Wildemuth, de Bliek, Friedman & File (1995) also investigated domain expertise, and expert search ability. They reviewed a number of studies that used various methods of measuring domain knowledge and its impact on information retrieval. They concluded that with regard to domain knowledge and retrieval effectiveness (measured by the ability to answer factual questions based on information retrieved from searches), results were mixed: data did not support conclusions either way for the efficacy of domain knowledge or otherwise.

With regard to a relationship between domain knowledge and the search process, again they found the evidence concerning any relationship with domain knowledge to be "inconclusive".

With regard to the selection of search terms, Wildemuth et al (1995) concluded that results from the three studies they reviewed (Allen, 1991; Hsieh-Yee, 1993 and Shute and Smith, 1993) suggested that domain knowledge will affect the "type and number of terms selected for incorporation into the search strategy" (Wildemuth et al, 1995:592).

In the study by Wildemuth et al (1995), 64 first year medical students at the University of North Carolina conducted searches on three different biomedical domains, on four assessment occasions over an 18 month period. Subjects'
ability to answer clinical problems in the three domains were used to measure
concluded that there is no strong relationship between a searcher’s domain
knowledge and his or her ability to search effectively in that domain. Further,
they concluded that their findings supported prior studies that found a
relationship between selection of search terms, and search effectiveness. They
also found that searching efficiency develops over time, and is transferable to
other databases. This finding is important, as other research (Perfetto,
Bransford & Franks, 1983 in Komatsu, ed. 1994) has found that problem-
called for further research into “searchers’ selection of search terms, ... and
mechanisms enabling the development of domain-specific problem-solving
skills related to searching and database use”.

On a point of terminology, Basch (1993) observed that the word “intermediary”
- often used to describe search experts - is not really accurate. Search experts,
she argued, are neither channellers nor gatekeepers; rather, they possess a
combination of logic, linear thinking, intuition and creativity; they enjoy the
excitement of a novel search and are very willing to share their knowledge
with others. Ehrlich & Cash (1994b:3) described the development of search
expertise as “a matter of temperament and personality - a certain combination
of patience, curiosity and self-reliance”.

Summary
Expert searchers exhibit the ability to use problem-solving heuristics; to
distinguish relevant from irrelevant information (because of superior domain
knowledge); and to perceive meaningful patterns in their domain of expertise.

An information-literate student may never acquire the domain knowledge that
enables expert searching to occur in a specific knowledge domain. However, in
our information society, arguably it is not domain knowledge alone that can
lead to success; the ability to locate, evaluate and articulate the significance of information is increasingly a requirement. The tools to enable this - problem-solving, and conceptual knowledge - are used by expert search intermediaries, and can be taught.

It was observed earlier that information retrieval today is being performed increasingly by novice end-users who are characterized by a broad range of individual differences. In the next sub-section, individual differences that are thought to impact on information retrieval ability, are identified.

3.1.4 Individual Differences

Information retrieval is influenced by a range of cognitive and affective variables – the so-called “human factors” that interact with search skills to determine search outcome. These factors, or individual differences, were identified and classified by Fidel & Soergel (1983). They suggested, for example, that searcher characteristics such as personality; intelligence; cognitive style; logical/analytical mind; and type of education were relevant to search outcome. They identified education and training variables such as highest degree; and training history; as being important. Some of the more promising elements of the comprehensive list of variables compiled by Fidel & Soergel have been researched over the last two decades and in Table 3-1 below, key individual differences that have been explored with regard to search ability are listed.
Table 3-1: Individual Differences Affecting Search Ability

<table>
<thead>
<tr>
<th>Source of Individual Differences</th>
<th>Author</th>
</tr>
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</table>
| Ability to articulate a question | Saracevic, 1971  
|                                  | Borgman, 1983b |
| Academic major                   | Borgman, 1986 |
| Boolean operators                | Borgman, 1986 |
| Computer anxiety/ability         | La Lomia & Sidowski, 1993 |
| Conceptual understanding         | Borgman, 1983b  
|                                  | Sein & Bostrom, 1989 (in Balaraman, 1991)  
|                                  | Cheney, 1991 |
| Critical thinking                | Ehrlich & Cash, 1994a |
| Domain knowledge                 | Borgman et al, 1984 |
| Language ability and vocabulary  | Borgman, 1986  
|                                  | Saracevic & Kantor, 1988 |
| Learning style                   | Saracevic & Kantor, 1988  
|                                  | Balaraman, 1991 |
| Logical problem-solving skills and reasoning | Borgman, 1983b; Allen, 1992  
|                                  | Eisenberg & Small, 1993;  
|                                  | Ehrlich & Cash, 1994a |
| Mental models                    | Borgman, 1983b |
| Perceptual speed                 | Allen, 1992 |
| Personality traits               | Borgman, 1989 |
| Prior search experience          | Saracevic & Kantor, 1988 |
| Procedural understanding         | Borgman, 1983a,b; Borgman et al, 1984; Cheney, 1991 |
| Reluctance to seek instruction   | Borgman, 1986 |
| Spatial ability                  | Vigil, 1988; Borgman, 1989; Allen, 1992 |
| Technical aptitude               | Borgman, 1989 |
| Thinking style                   | Saracevic & Kantor, 1988 |
| Verbal ability                   | Allen, 1992 |
| Visual ability                   | Borgman, 1989  
|                                  | Balaraman, 1991 |

Borgman et al (1984) discussed a number of individual differences relevant to the present study. Firstly, supporting Saracevic's (1971) observation, they commented that an end-user's access to information is limited by his or her ability to articulate the question. Secondly, they observed that the length of time for end-users to learn all that is necessary, varies. Finally, they commented...
that a good searcher (for example, a search intermediary) needs several skills categories. These skills categories include general principles of searching; for example, concepts of information retrieval; problem analysis; and planning search strategies. Other skills identified were the ability to evaluate searches; logical problem-solving skills; academic skills such as subject area knowledge; and system-dependent skills (technical skills enabling manipulation of a specific database).

Egan (1988) and Borgman (1989) have both reviewed studies of end-user performance that have shown that the range of human performance on computing tasks is much greater than the range found on most other work tasks. Borgman (1989:237) reported studies that found that on non-computing tasks, 95% of persons have a performance range of 2:1, which means that it takes the person who is slowest at a task twice as long as it takes the person who is fastest at a task, to complete it. Further, she reported that these studies showed that by comparison, the average performance range for information retrieval tasks by novice searchers is 10:1; in other words, it takes the slowest novice searcher ten times as long to complete a task as it does the fastest novice searcher.

In 1996 Borgman revisited her work of a decade earlier (Borgman, 1986) on the use of online catalogues. She concluded that little has changed with the design of online interfaces, and that still, individual differences are not being taken into account. She observed that catalogue design "does not incorporate sufficient understanding of searching behavior" (1996:493). Further, that "online catalogs must serve a population of information seekers that is heterogeneous in terms of age, language, culture, subject knowledge, and computing expertise, most of whom will be permanent novices at information retrieval" (Borgman, 1996: 494).
One of the most comprehensive studies to date on the topic of human factors in information retrieval was that conducted by Saracevic & Kantor in 1988. The aim of the study was “to contribute to the formal, scientific characterisation of the elements involved in information seeking and retrieving, especially as they related to the cognitive decisions and human interactions involved” (Saracevic & Kantor, 1988:177).

In an attempt to identify more accurately these cognitive traits, the 36 search intermediaries participating in the study were given a number of pretests to determine their thinking style (the Symbolic Reasoning Test - SRT); language ability (Remote Associates Test); preferred learning style (Learning Style Inventory - LSI); and amount of prior searching experience (completion of a questionnaire). Saracevic & Kantor found that searchers who had a higher ability in language, for example; word association, retrieved more relevant items than those searchers with less developed language ability. Those searchers who were abstract thinkers achieved higher relevance and recall results than those searchers with a preference for, say, concrete learning experiences. Further, Saracevic & Kantor found that overlap in the selection of search terms for a question by different searchers, was relatively low. Searchers seemed to extract different language from the same question, or interpret the question differently, or retrieve different sets from the same database.

Finally, Saracevic & Kantor found that the best recall for a search question was done from a taped problem and intent statement provided by the end-user. The worst recall resulted from the searcher using words from written questions taken as search terms. Interestingly, Spink & Saracevic (1997) when further analysing the 1988 data reported that search terms derived from written question statements, combined with search terms suggested through users’ domain knowledge, produced half of the relevant searches (compared to thesaurus terms, term relevance feedback terms and intermediary terms).
Allen (1992) conducted a study in which 50 university students were tested on four indicators of cognitive ability: verbal comprehension (the ability to understand the English language); logical reasoning (the ability to reason from premise to conclusion); perceptual speed (speed in comparing figures or symbols); and spatial scanning (speed in exploring visually a wide spatial field). He found differences in search outcomes according to perceptual speed, which had an effect on search quality; and logical reasoning and verbal comprehension, which influenced search tactics. Allen suggested that other indicators of cognitive ability also needed to be researched.

Biehler & Snowman (1993:145) identified 21 variables which have been demonstrated through research to influence student achievement in general; for example, age, attention span, cognitive style, ethnicity, gender, learning style, motivation, perceptual skill, prior knowledge, problem-solving ability, self-concept, and stage of cognitive development. Biehler & Snowman observed that there will also be differences in performance shown by one individual over time, depending on a range of environmental, social, psychological and emotional factors.

Szajna & Mackay (1995) discussed three areas of individual differences which have been identified as important for general computing skills: psychological factors (such as computer anxiety); cognitive factors (such as computer aptitude); and experiential factors (such as computer experience). As information from online or offline databases necessitates the use of computers, these factors must also be considered.

3.1.5 Issues in Information Retrieval - Summary

Most searching today and in the foreseeable future will be done by end-users who are "permanent novices", with little understanding of the complexities of electronic database searching. As a result, "false positive" results occur, and end-users see little use in spending time learning to use databases. Typical
problems encountered by such inexperienced searchers are inadequate
identification of concepts, lack of use of synonyms for those concepts that are
identified, incorrect use of truncation, and logical errors.

Whilst good search results can be obtained using either well-developed domain
knowledge, or well-developed search skills (problem-solving orientation), it is
the problem-solving approach of expert search intermediaries that should be of
most use to the typical end-user of today, as the ability to gather information
on a wide range of topics is increasingly a requirement in today's workforce.

Individual differences that impact on information retrieval performance
include: the ability to articulate the question; conceptual knowledge; learning
style; problem-solving ability; critical thinking; domain knowledge;
computer/technical aptitude; and prior experience.

As Robertson & Hancock-Beaulieu (1992:464) observed, "we are moving in the
direction of a broad view of information retrieval systems encompassing
human activities well away from the mechanism". In other words, what
happens before the search; how a search is conceptualised; the cognitive
dimension; and individual differences, are now recognised as part of the
information retrieval system.

In the next section, theoretical representations of the information retrieval
process are discussed.

3.2 Models of Information Retrieval

In the previous section, the nature of the information retrieval task was
discussed. This discussion focused on describing the range of tasks and
capabilities that appear to be involved in information retrieval; that is, the
"what" of the information retrieval process.
Based on these observations and descriptions, a number of researchers have theorised as to the “why” and the “how” of the information retrieval process. These theories vary somewhat as to the scope of tasks included in the information retrieval process, and in their conceptualisation. Theories representative of studies undertaken in the last 15 years are discussed below.

3.2.1 Borgman

Borgman (1983a,b) described the utility of the “Mental Models” theory in explaining end-user behaviour and online searching. Borgman described a mental model as “a qualitative simulation of system behavior which can be ‘run’ in the mind” (1983a:23). The mental model is unique to each individual, varies in complexity, and changes to accommodate new detail or fresh experiences.

The possession of a mental model usually indicates that a person has a conceptual understanding of searching, as opposed to merely a procedural knowledge of a particular system’s operation. The conceptual understanding allows easier identification of search errors, as it allows the generation of alternative means to achieve the desired search outcome.

Borgman (1983a,b) suggested that when training end-users, care should be taken to consider their expectations; that is, to explain what the system can and cannot do. Secondly, she suggested that it was necessary to be aware of end-user fears and perceptions. Finally, she suggested that it was necessary to avoid representing the system as more or less than it is, in order for the end-user to be able to formulate reasonable expectations of a system’s capabilities. Results from her experimental study (1983b) however, indicated no significant differences in information retrieval performance between groups taught with a conceptual model, and those who were not.
In 1996 Borgman developed further her model of searching first put forward in 1986. The original model distinguished between two types of knowledge applied by searchers to the information retrieval process: mechanical knowledge (for example, syntax and search structuring); and conceptual knowledge (the “why” of searching, used to develop alternative search paths etc). In 1996 Borgman differentiated this model into three layers of knowledge required for information retrieval: conceptual knowledge - translating the information need to a suitable query format; semantic knowledge (the meaning of computing and task concepts - the how and when to use system features); and technical skills in running the query - basic computing skills.

Borgman concluded that instruction too often concentrated on teaching technical skills, and failed to cover the more important semantic and conceptual knowledge.

Saracevic & Kantor (1988) discussed the requirements of a theory of information seeking and retrieving, and suggested that, inter alia, a useful model would have to incorporate elements of context and content of information; and individual differences in patterns of concept formation.

3.2.2 Kuhlthau

Kuhlthau (1988) described a qualitative study of 26 high school seniors from top English classes – chosen for their ability to describe their thoughts, feelings and process of an information search for two English papers over a school year. Detailed information was gathered concerning students’ thoughts about the topic, the search process, the information they had found (recorded in journals); transaction log information, interviews and the drawing of timelines. Kuhlthau was seeking both to test elements of three cognitive theories relating to the search process, and to gather data as to the thoughts and feelings of users of information from the time a search topic was received, to the time when writing began. Kuhlthau developed a six stage model of the entire search process: task initiation, topic selection, prefocus exploration, focus
formulation, information collection, search closure. At each stage, feelings, thoughts and actions were described. Frequently, for example, subjects reported a change of feelings between the "prefocus exploration" stage and the "focus formulation" stage, from confusion and frustration to clarity. Kuhlthau’s process model was very useful in terms of describing the changing nature of "information problems" (Kuhlthau, 1988:241) that are experienced by students.

Kuhlthau’s model takes into account the way ideas and attitudes about the topic and process change as the search progresses (based on the work of Kelly, 1963 in Kuhlthau, 1988). This "constructivist" approach suggests that the search is altered as the searcher’s construct of the question changes.

The process identified by Kuhlthau (1988) was used to develop teaching strategies and activities to be of use to students as they progressed through the stages of the research process. They are described in Kuhlthau (1994). In these activities, Kuhlthau takes into account Piaget’s classification of cognitive developmental levels, observing that in her opinion students need to operate at the formal level of development in order to be able to conduct library research.

3.2.3 Bates

Bates (1979, 1981, 1990) distinguished between search strategy: "a plan for the whole search" (1979:207); and search tactic: "a move made to further a search" (1979:207) for example, relate, trace, rearrange. Bates suggested that there are four useful categories of models of search strategy: models for idealising searching (ideal search patterns based on system analytic or other criteria); representing searching (descriptions of human search behaviour); teaching searching, and facilitating searching (helping the searcher in the search process) (1979:206; 1981:154).
In 1989, Bates proposed a “berrypicking” model for representing searching. She suggested that a “real world” search is continually evolving; that not only search terms, but also the conceptualisation of the search query itself, changes during the search. Bates called this “bit-at-a-time” retrieval “berrypicking” (1989:410).

3.2.4 Marchionini

Marchionini (1995) described an information seeking process comprising a series of iterative sub-processes: recognise and accept problem; define problem; select source; formulate query; execute query; examine results; extract information; and reflect/iterate/stop. Marchionini suggested that some of these sub-processes run in parallel; for example, the sub-process “define the problem” remains active throughout the information seeking process (1995:51). The sub-processes are further arranged into three classes: understanding (recognise; accept; define); planning and executing (select system; formulate query; execute and examine); and evaluation and use (examine; extract; reflect/iterate/stop (1995:58). These sub-processes are supported by ongoing judgments as to search progress.

Marchionini (1995:73) also classified information seeking strategies along a series of continua: analytical strategies, which are planned, goal directed, deterministic, formal and discrete; and browsing strategies, which are opportunistic, data driven, heuristic, informal and continuous.

3.2.5 Spink

In 1997 Spink argued for the need for information seeking and retrieving models to incorporate a feedback loop, in addition to that for relevance alone. She discussed cybernetic and social types of feedback.
3.2.6 Wilson

Wilson (1998) suggested the importance of a problem-solving conceptualisation of search behaviour, observing that models of single process searching needed to take into account the fact that it is more typical that searchers engage in successive searches on the same problem. Wilson described the successive search process in terms of uncertainty reduction, beginning with problem identification, moving to problem definition, problem resolution and finally, the solution statement.

3.2.7 Limberg

Limberg (1999) described the phenomenographic research she conducted with 25 high school seniors (aged 18-19 years) through interviews while they worked in small groups on research papers about Sweden entering the European Union. Limberg found that students' conceptions of information seeking were fact-finding; balancing information in order to make correct choices; and scrutinizing and analyzing. The content of the papers written corresponded to these categories; that is, a student who had a conception of information seeking as fact-finding, tended to produce a paper that was fragmentary, with insufficient knowledge and analysis demonstrated. Limberg observed the similarity between such conceptions, and Perry's developmental levels in adolescence and early adulthood.

Summary

Models of information retrieval have evolved as research has improved our understanding of the process. Each has been a valuable contribution to the understanding of the information retrieval process; each has left questions remaining to be answered.

In 1983 Borgman tested the efficacy of conceptual models in developing information retrieval ability, but found no significant differences between
treatment groups. Kuhlthau (1988, 1994) suggested a “constructivist” search process that takes into account the modification of ideas as new information on the topic is encountered, but did not suggest a mechanism to account for these modifications. She also noted the possible significance of Piaget’s work in developmental psychology, and the need for searchers to be operating at the “formal” level of cognitive operations in order to search effectively, but did not suggest how this may relate to the search process.

Bates (1989) suggested an interesting “berrypicking” model of the search process, but did not hypothesise as to the thinking structures that might underpin this “berrypicking” process, or why the conceptualisation of the search process changes as the search progresses.

Marchionini (1995) described information seeking as a series of iterative sub-processes supported by ongoing judgments; but although the role of cognitive input is discussed, he does not discuss the nature of this input, or how the “understanding” class of sub-processes might work in detail.

Marchionini also discussed a valuable distinction between analytic and browsing information retrieval strategies, the former treating information seeking as dependent on “careful planning, the recall of query terms, and iterative query reformulations and examinations of results” (Marchionini, 1995:8).

In 1997 Spink discussed the importance of feedback loops in modeling the search process, over and above simple relevance judgments, while Wilson (1998) suggested the importance of a problem-solving conceptualisation of the search process, the purpose of which was uncertainty reduction.

Finally, Limberg (1999) found that students with a conception of information retrieval as fact-finding tended to produce papers in which little analysis was
apparent; and made the observation that there was a similarity here to Perry's "dualistic" stage of cognitive maturity.

In the first section of this chapter, characteristics of the information retrieval process were described. In the second section, models representing the process were reviewed. In the next section, developments in the teaching of information retrieval are discussed.

3.3 Teaching Information Retrieval

As early as 1983, problems with the teaching of online searching were identified. Lipow (1983:58) listed several difficulties: firstly, the more "friendly" the system, the more likely that end-users would be lulled into (falsely) believing that they could use the system quite well; secondly, a sizeable percentage of end-users will always misuse or misinterpret an online catalogue; and thirdly, no matter how good an instructional method is, there will always be a significant number of end-users not reached by it.

A number of articles have addressed the efficacy of demonstration versus hands-on computer instruction; for example, Ramaoka (1995); Davis & Bostrom (1993); and Barbuto & Cevallos (1991). 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 indicate little difference between treatment groups.

3.3.1 Concept-based Teaching

Other research over the last 10 - 15 years has pointed to why a cognitive, conceptual approach to information retrieval instruction could be a more
fruitful avenue to investigate, as these studies emphasised the need to teach end-users how to develop a conceptualised understanding of the search process.

Borgman (1983b) for example, conducted a doctoral study using 28 Stanford University students in an experimental research design to test the efficacy of concept-based instruction, hypothesising that concept-based instruction: would improve search performance on difficult search questions; and would facilitate the development of a mental model of the search process. Results however, were not significant.

Kohl & Wilson (1986) provided one of the first discussions of the content of bibliographic instruction sessions, as opposed to simply the method of delivery. Kohl & Wilson conducted an experimental study in which two groups of students were given different types of bibliographic instruction. One group received "traditional" instruction which focused on a "one size fits all" approach, advocating research starting with encyclopaedias and dictionaries. The other group received instruction that recommended that students first answer three questions about the search topic before they began their search. These questions concerned the discipline involved in the question, the kind of information required, and the time frame necessary for the search (ie, contemporary information, or retrospective). The 178 bibliographies (90 in the "cognitive strategy" group; 88 in the "traditional" group) for papers generated by the searches were rated to determine whether or not items found were relevant. Results indicated a statistically significant difference between the two groups, with the cognitive strategy group performing the better of the two. Kohl & Wilson concluded that bibliographic instruction should begin with the student's research question, rather than the library tool on its own.

Sylvia & 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 & 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 & Kilman (1991:46) 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".

In contradiction to findings that suggested the possible efficacy of the use of concept-based teaching, a study by Young & Ackerson (1995) suggested no significant difference between the two methods of instruction in four of the five semesters of their research. In their study at the University of Alabama, Young & Ackerson compared a "traditional" 50 minute library lecture delivered to control groups totalling 122 subjects, with a "course-specific" approach (50 minute library lecture plus three hours of other instruction in online searching) delivered to experimental groups totalling 129 subjects. A rating sheet based on Kohl & Wilson's (1986) instrument was used to evaluate bibliographies compiled in the course of research. Their result did not support results of Kohl & Wilson (1986), on which elements of the Young & Ackerson study were based.

As Young & Ackerson acknowledged, however, their results were subject to a number of intervening variables, such as assistance given by library reference staff to both experimental and control group subjects. Further, as Young &
Ackerson (1995:88) observed, the librarians teaching the experimental group did not discuss differences between scholarly and popular sources, even though these distinctions formed part of the ratings scale.

Zahner (1992) conducted a doctoral study with 190 first year subjects at Valdosta State College, Georgia, USA, using an experimental research design. In that study, 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, was investigated.

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 (evaluation of thinking processes and progress towards problem solving) dimensions of the search process 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; for example, 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, quality of sources located was evaluated using a checklist. Results suggested that this “cognitive strategies” instruction resulted in significantly better research paper bibliographies, than those of the “traditional approach” treatment group.

Finally, Dixon & Gabrys (1991) reported that conceptual knowledge of complex computer “devices” may not necessarily transfer to new situations as effectively as does operational [skills-based] knowledge. In their study, Dixon & Gabrys examined transfer of training in terms of operating complex devices
such as a “new type of banking machine” (an automatic teller machine). They found that conceptual instruction did not improve ability to operate the machine. They argued that the time taken to acquire a “deep conceptual understanding” may not be warranted when learning to use such devices (1991:103), although a “conceptual understanding may aid users ... when the amount of prior learning is small” (1991:119).

While Dixon & Gabrys’ findings regarding the lack of efficacy of the development of conceptual knowledge are relevant to the use of simple interfaces such as automatic teller machines, they do not necessarily apply to complex interfaces such as electronic databases. Moreover, many members of the undergraduate end-user population fit into Dixon & Gabrys’ exception category of little prior learning.

Summary

Sein & Bostrom (1989, in Balaraman, 1991:284) have commented on the “puzzling display of weak effects of conceptual models”. They observed that the efficacy of conceptual models is supported by theory, yet empirical evidence of their use is scanty or ambiguous.

In the next sub-section, the efficacy of problem-solving heuristics in the teaching of information retrieval is discussed.

3.3.2 The Role of Problem-solving Heuristics

In the context of reasoning and information retrieval, Chen & Dhar (1991) observed that with both novice and expert searchers, the major problem is not search mechanics, but search strategy. The combination of query formulation, and choice-making when determining search strategy, combine to form search uncertainty, which can be very stressful for novice searchers in particular. Without reasoning and critical thinking skills, this uncertainty is difficult to resolve satisfactorily.
Bransky, Hadass & Lubezky (1992) discussed the inadequacy of adult reasoning, the control of variables, and logical conclusions in problem solving generally. Results of their study suggested that student teachers do not realise when they have insufficient information to reach a conclusion.

Biehler & Snowman (1993) discussed "well-structured" and "ill-structured" problems. In general, well-structured problems are clearly formulated and can be solved by applying a procedure, known as an algorithm. On the other hand, ill-structured problems are more complex, parameters are often uncertain, and all elements necessary to solve the problem may not be known. Borgman (1996:494) described information retrieval as a difficult problem, because "it requires describing information that you do not yet have."

Further, Wallace (1993) when replicating Borgman's (1989) studies, found a striking feature was the difficulty searchers have in reformulating search strategy, especially when they obtain zero results. Often, end-users would conduct the same search on an inappropriate database, or abandon the search altogether. Wallace observed that end-users should be encouraged to approach any search session with the assumption that they will find some information and that what is required for success is a process or plan of action. Confidence in the outcome of the search is essential, and good instruction builds toward that psychological "edge".

Ury, Johnson & Meldrem (1997) discussed the efficacy of an heuristic model in the teaching of information retrieval. Students were encouraged to use the model to help them "generate strategies for exploring and evaluating a broad spectrum of resources" (Ury et al, 1997:40).

Yerbury & Parker (1998) conducted a study with 28 undergraduate information retrieval students at the University of Technology, Sydney, Australia. Yerbury
Parker concluded that when memory for operating procedures in information retrieval is not complete, unconscious use of a conceptual system—such as a problem-solving heuristic—which helps to guide the end-user through the search process may lead to success. Yerbury & Parker (1998:213) concluded that in the teaching of information literacy skills, "the crucial component may be the identification of an appropriate problem-solving strategy", including how to identify the structure of problems (search queries) for students to use, enabling the invoking of conceptual structures that will guide a search. Yerbury & Parker (1998:213) called for further study that investigates the relationship where "traditional skills of information retrieval are needed alongside newer conceptualisation of problem-solving, adopted from other areas of practice.”

3.3.3 Course-integrated Instruction

The linking of bibliographic instruction to specific academic subjects, known as course-integrated instruction, is another issue relevant to this study. In course-integrated instruction, class teachers and librarians work in partnership to promote the use of library resources and the "development of critical thinking skills in information use" (Franklin & Toifel, 1994:225). Course-integrated instruction seems to be favoured in the current literature as it enhances learning outcomes and makes bibliographic instruction more relevant when linked to particular search (essay) requirements.

Reese (1993) discussed a variety of teaching options available for bibliographic instruction, and concluded that course-integrated instruction is very useful. She also discussed the importance of conceptual instruction, which can prepare a person to use many different types of electronic systems.

Rowe (1994) reported that subject-specific course-integrated instruction was the focus of literature she reviewed, and the ten libraries surveyed in her study - all
under the control of the Florida State University system -were developing instruction along those lines.

Ragains (1995) summarised problems with library-based one-off bibliographic instruction sessions as: difficulty in establishing rapport; difficulty in imparting a lot of information in a short time; and a tendency to impart facts rather than encouraging higher cognitive processes.

Farber (1993 in Ury, Johnson & Meldrem 1997:39) remarked on a common attitude of undergraduates to the acquisition of information retrieval skills: “Learning how to use the library does not really impress most students until they need it for a particular course or assignment.”

Summary
Many studies investigating the efficacy of different methods of teaching information retrieval from electronic databases have focused on different modes of delivery of skills training. Results generally show little difference between treatment groups; for example, hands-on, or demonstration. Interest in concept-based teaching, however, and the recognition of the role of problem solving in the search process, is increasing (Bruce, 1998). Results to date suggest the efficacy of some type of concept-based teaching.

In the next section, issues relating to methodology in information retrieval research are discussed.

3.4 Methodologies in Information Retrieval Research
As discussed in the previous section, many studies to date that have examined the relative efficacy of teaching methods in information retrieval instruction have compared only methods of skills instruction, for example, “hands on” instruction, or demonstration (Ramaoka, 1995; Davis & Bostrom, 1993). These studies have had mixed results. Secondly, a number of studies, also with mixed
results, have suggested that information retrieval requires conceptual knowledge and problem-solving ability, as well as skills training in the mechanics of database operation. As Balaraman (1991) observed, a majority of researchers has found an interaction between some form of conceptual training and the task performed; but although there is a strong theoretical basis for conceptual models, there is little empirical evidence of their efficacy (Oberman, 1991; Sein & Bostrom, 1989 in Balaraman, 1991). An exception is Zahner (1992).

Further, a number of the studies that have been conducted may not be methodologically rigorous. In a survey of some 16 research studies conducted on end-user search behaviour during the late 1980s in the United States, Seymour (1991) concluded that the methodologies in general were by no means as rigorous as they could, or should, have been. Fine (1984, in Dalrymple & Zweizig, 1992) noted that a major limitation in the way behaviour research is conducted in librarianship in general is the failure to build research on fully described and developed constructs.

Edwards (1994) analysed 595 articles on bibliographic instruction from 21 journals covering the period 1977 to 1991. Of these, 178 articles were classified as research. She concluded that although the number of articles nearly tripled in that period, research articles as a percentage of the total output have remained stable at around 30%. Of that 30%, only 12.4% followed an experimental research design. Most of the research articles were on effectiveness of bibliographic instruction, or information-seeking behaviour of library patrons. Watson-Boone (2000) discussed a study she had completed on the number and type of research articles published in the Journal of Academic Librarianship from 1985 to 1995. Watson-Boone noted that over that ten-year period, covered by eleven issues of the journal, only 56 articles had been research-based. Twenty-four (43%) were written by "practitioner-researchers" (information professionals who also conduct research); only one of those
followed an experimental design. Survey research accounted for twelve (50%) of the practitioner-researcher articles reported.

Rochester (1995) conducted a content analysis of articles published on library and information science research in Australia from 1985-1994. She found that 24% of published articles were on research; 83% of these used empirical research methods. Forty-four per cent of these empirical articles used surveys, followed by the historical method at 14%. Rochester also reported that studies on user education in that decade numbered only six of 126 research articles.

Similarly, Seymour (1991) in her analysis of 16 American library research methodology studies of online public access catalogs, found that in nine of the 16 articles, research was conducted using surveys or questionnaires, all of which suffered from sampling problems. Only three of the remaining studies were of an experimental design. One of these was Borgman's study on mental models (1983b). Seymour (1991:100) concluded that “experiments in controlled environments ... can yield very basic and useful results”, but that methodological expertise was lacking in most of the research she had surveyed.

In the final section of this chapter, characteristics of information retrieval, models of information retrieval, and teaching and learning issues are drawn together, and the scope for research that is implied by their combination is described.

3.5 Conclusion

An increasing understanding of the role of individual differences in the use of information retrieval systems suggest new approaches to end-user education are required. From the previous discussion, it would seem that one of the most important functions of the user interface is to provide procedural training, but a conceptual model of the system has to be learned first.
In this chapter, issues in information retrieval have been canvassed, particularly as they apply to the retrieval of information from electronic databases. Research into human factors in information retrieval suggests that in an age of "permanent novices", such factors as education, problem-solving ability and computer expertise need to be considered in the teaching of information retrieval.

The literature reviewed suggests that elements central to the development of a sound conceptual and procedural understanding of the search process include: the ability to draw on a mental model of the search process including understanding the limitations of databases; a problem-solving heuristic; and search mechanics, including strategy, concepts (synonyms, vocabulary), and logic.

The question arises - which theory(ies) of teaching and learning are most likely to support the development of a conceptual understanding of information retrieval? The researcher reviewed a number of current teaching/learning theories, including social learning theory, action research and experiential learning, and found that many of the underlying tenets of these theories stem from the discipline of cognitive psychology.

Further, a number of models have been developed to represent the information retrieval process. These models have included (separately, but not in combination), conceptual knowledge, procedural knowledge, problem solving, iteration, critical thinking, and the possible utility of cognitive processes and maturity in successful information retrieval.
Cognitive psychology provides solutions to a number of questions surrounding issues in information retrieval through three converging paths which provide: firstly, a theoretical basis for the development of a model of the information retrieval process; secondly, sound teaching and learning paradigms which generate practical methodologies for instruction; and finally, an explanation of observations of individual differences, and differences in cognitive development between students.

Each of these elements will be discussed separately in the next chapter.
4. COGNITIVE PSYCHOLOGY - A REVIEW

In the previous chapter, literature pertaining to information retrieval was reviewed. Issues considered in that discussion included: elements of electronic database searching; expectations of novice searchers; the nature of expert searching; and human factors, such as problem-solving ability, age, or education, that influence search behaviour.

Models of information retrieval, teaching and learning, and methodological issues were discussed.

In this chapter, the elements of cognitive psychology are discussed. Cognitive psychology is a discipline that provides useful insights into the information retrieval process, informing our understanding of that process, and providing concepts that are useful in the construction of models of that process. Further, general theories of learning suggested by cognitive psychology would appear to have significant implications for the design of information retrieval instruction in particular, and the acquisition of information literacy in general.

Information processing theory (section 4.1) suggests a number of propositions about the nature of concept formation and problem solving that may be of relevance to the understanding of the information retrieval process and to the modeling of that process. Information processing underpins the teaching strategies suggested by cognitive learning theorists.

In section 4.2, cognitive learning theories, addressing the nature of the teaching and learning process, are reviewed. These theories - transforming mental models, cognitive flexibility theory, and situated cognition - suggest a
number of practical teaching initiatives that may assist the achievement of information retrieval effectiveness.

Finally, in section 4.3, cognitive developmental theory is discussed. Developmental theory investigates and describes the universal, developmental nature of thinking and problem solving. The theory suggests that formal, mature thinking processes cannot be assumed, even in tertiary education. Such a proposition has significant ramifications for the teaching of information retrieval to undergraduate students.

4.1 Information Processing

Psychology is the study of behaviour. Behaviour is divided into three broad categories: social; emotional; and intellectual. These three types of behaviour can be analysed at three different levels: behavioural (readily observable actions); physiological (the physical structures underlying the thinking process); and cognitive (the actual thinking process). Table 4-1 shows the matrix of possible combinations of study in psychology that result from the interplay of these six conditions.

<table>
<thead>
<tr>
<th>Level of Analysis</th>
<th>Type of Behaviour</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Social</td>
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<tr>
<td>Behavioural</td>
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<tr>
<td>Physiological</td>
<td></td>
</tr>
<tr>
<td>Cognitive</td>
<td></td>
</tr>
</tbody>
</table>

Source: Gagne, Yekovich & Yekovich, 1993:4

Using this framework, cognitive psychology is the study of the thinking processes (level of analysis) that underlie intellectual behaviour (type of behaviour). As Glaser (1990:38) observed, "the single most important
contribution to instruction theory, to date, of the knowledge and methodology of cognitive science has been the analysis of complex human performance”.

Information retrieval is a complex intellectual behaviour. Analysis of information retrieval behaviour at the cognitive level enables the development of a model of the information retrieval process, the design of appropriate strategies for the teaching of a conceptual understanding of the information retrieval process, and an explanation of how individual differences influence performance on information retrieval tasks.

Information processing research is largely non-development. That is, any changes in performance by individuals are attributed to changes in experience, for example, novice-expert differences, or to differences in learning style (ter Laak, in van Geert, 1986).

In sub-section 4.1.1, terms used in cognitive psychology that are relevant to the current research are discussed.

4.1.1 Knowledge Representation

Knowledge representation refers to the way information is arranged and ordered in the human mind. The construct provides a useful explanation of the components of the bibliographic search process. There are two types of knowledge representation according to cognitive psychology: declarative; and procedural (Ryle, 1949 in Gagne, Yekovich & Yekovich, 1993).

Declarative knowledge comprises facts, figures and concepts. It is declarative knowledge that allows us to answer such questions as Who is the Prime Minister of Australia, or Identify two factors contributing to World War I.

Declarative knowledge can be represented in memory in three ways: networks; analogs; and linear representations.
The network comprises a series of linked propositions (Collins & Quillian, 1969 in Gagne, Yekovich & Yekovich, 1993). A network of concepts, or propositions, is unique to each individual. One person's knowledge representation of the concept animal, for example, will be different from another person's representation of the same concept. Similarly, one person's knowledge representation of the concept "search" will be different from another person's. The connections between concepts allow us to retrieve information from memory and to solve new problems. Each part of the concept is part of a network of propositions; each proposition is linked to one or more other propositions to form a unique network, or schema.

A schema is a representation of an experience or a concept. Recent research in cognitive psychology has focussed on this knowledge structure. Schemas are often not discrete; that is, elements of one schema may overlap with elements of another to form a "tangled network" (Marshall, in Frederikson, Glaser, Lesgold & Shafto, eds., 1990:441). For example, a schema for a visit to a petrol station might include petrol pumps, filling the tank, paying for the petrol, and perhaps putting air in the tyres. Even though each petrol station will have minor differences in appearance and layout, size, price and so on, the concepts that form the schema for going to the petrol station will remain the same in their essentials. The more petrol stations visited, the more variations to the schema are possible, and the more detailed and accurate the schema becomes.

In a similar fashion, a schema, or mental model, of the search process might include "read question, identify concepts, identify synonyms, identify databases, formulate search strategies, run search". The more searches conducted and the more databases used, the more detailed and accurate the schema will become. If enough experience is gained, the searcher will move from novice, to intermediate, and perhaps to expert, status.
Schemas can be linked together to form systems, or networks. For example, a schema of “picnic” could be linked to “parties” and “outings”. A schema has “slots” which are filled with either compulsory or variable values (Rumelhart & Norman 1983, in Cohen, Kiss & LeVoi, 1993:28); for example, the “picnic” schema might have compulsory slots - “outdoors”, and “food” - but variable values could be “by the river” and “chicken”.

The second method of representing declarative knowledge is the analog, or image (Moyer, 1973 and Anderson, 1990 in Gagne, Yekovich & Yekovich, 1993). For example, when answering the question *Is a bus larger than a car?* most people will (unconsciously) draw on images of these objects stored in memory to answer the question, rather than on a network of concepts or propositions about cars and buses. The use of analogs enables the rapid comparison of these two different images, and a decision to be made about their similarities and dissimilarities.

The third method of storing declarative knowledge is the *linear representation*, or *sequence*. Studies which have provided evidence of memory through sequencing have used the way letters of the alphabet are remembered in short one-way sub-sequences (for example, ABCD ... EFG), and the speed of recall of these sequences, to demonstrate the linear nature of some memories (Potts, 1972 in Gagne, Yekovich & Yekovich, 1993).

Declarative knowledge is relatively easy to acquire, and to change. As new knowledge, or variations of a concept, are learned, these new elements can be added to a schema, which is then modified to accommodate the new information. When declarative knowledge is retrieved, the process is usually unconscious, and the several modes of knowledge representation are accessed and searched simultaneously. For example, if a person is presented with a picture of an animal which is unfamiliar to them, they will unconsciously conduct a rapid simultaneous search of their declarative
knowledge base (probably networks of their concepts of animal, or their analog representations of animal) in an attempt to classify the animal or to match it to an existing image in memory.

In the context of the search process, when an end-user is presented with an essay question (search topic), they will unconsciously conduct a rapid search of their declarative knowledge base in an attempt to anchor it to an existing schema in memory.

The second type of knowledge representation in human memory is procedural knowledge. Procedural knowledge is knowledge of routines or sequences for performing a given task; for example, a sequence of steps for executing a long division task in mathematics. A procedure is represented in memory as a production (Schunk, 1991); that is, a series of IF ... THEN rules. A sequence takes longer to become embedded in memory than does declarative knowledge. With regular use, it becomes automatic over time. Once memorised, the procedure is difficult to change.

Gagne, Yekovich & Yekovich (1993) suggest that the length of time required for a sequence to become automatic is a protective mechanism. If an automatically performed procedure is an inappropriate one, it could possibly cause danger to the individual. For example, with driving a car, if an inappropriate sequence for “entering a roundabout” that omitted the step to “give way to vehicles already in the roundabout”, was rapidly automaticised, the difficulty of changing the sequence would expose the individual to considerable danger until that inappropriate sequence could be extinguished. It follows that procedural knowledge becomes automated for experts, but is slow and conscious for novices (Gagne, Yekovich & Yekovich, 1993).
In the context of search behaviour, novices tend to be very slow and deliberate in their selection of search terms and databases, and formulation of search strategies; experts may not even be aware consciously that they have performed these steps.

One final point of relevance to the present discussion is the relationship between two continua: the domain generality/specificity of a procedure; and the level of control/automaticity of a procedure. Domain-general strategies can be used across a variety of situations. Domain-specific strategies are procedures that are tailored to a particular discipline. Usually, domain-general strategies are procedures that are under conscious control. For example, a general problem-solving heuristic may be recalled to solve a novel problem, such as how to travel from Sydney to New York by Friday of the following week. In contrast, domain-specific procedures are detailed, and tailored to a specific environment. They are therefore more accurate and effective than domain-general procedures. Domain-specific procedures tend to become automated - but not completely - for experts in a field. For example, as mentioned earlier, an expert search intermediary such as a librarian may use a number of production sequences during routine searches quite automatically. However, when a novel or difficult search task is encountered, the procedure more likely would be controlled; that is, a conscious, sequential thought process would be used.

The conversion of declarative knowledge to proceduralised knowledge takes place through the process of knowledge compilation. Anderson (1983, in Glaser, 1990), postulated that novices may possess a certain level of declarative knowledge, but will lack the domain-specific understanding that would enable that declarative knowledge to be converted to an expert-level production sequence, as they do not understand the "conditions of effective application" (Glaser, 1990:30) of that knowledge to that particular domain.
According to Anderson (1983, in Glaser, 1990), knowledge compilation comprises two elements: **proceduralisation** and **composition**. Proceduralisation refers to that mechanism whereby novices initially think in terms of concepts (that is, declarative knowledge). Gradually, with experience, this knowledge becomes proceduralised, as the "problem states" before and after generating the solution are compared, and a procedure for achieving that solution in the specific domain is learned.

The second phase of compilation - composition - occurs when that sequence of procedures, through repetition, is collapsed into a single large "chunk" of information that can be recalled and executed automatically when necessary (Glaser, 1990). Earlier in this discussion, it was noted that one means of storing and retrieving declarative knowledge is the linear sequence.

"Chunking" is the term used to describe the phenomenon that experts in a domain tend to be able to remember much longer sequences of information than can novices. It is thought that this is because experts order and classify information in such a way that it is more easily stored and assimilated into existing knowledge representations, and so it is also more easily retrieved. Thus an expert when analysing a problem may be identifying totally different features of that problem as relevant, in comparison to the analysis of a novice (Glaser, 1990).

Further, an expert will tend to remember meaningful information and patterns, and examine only relevant solutions, compared with novices (Holyoak, in Osherman & Smith, eds, 1990). Holyoak describes Chase & Simon's (1973) study of chess players, that suggested that chess masters will remember real chess game configurations more accurately than do novices. Chase & Simon concluded however that better memory was not the reason for the better performance, as when chess pieces were randomly placed on the chess board, memory of the positions was no better for masters than for novices. Chase & Simon suggested that masters are better able to recognise
and retain significant patterns. This recognition enables them to recall and mentally test a limited number of relevant strategies. A novice, on the other hand, fails to recognise patterns, and wastes time trialling multiple, ineffective, strategies. These results could explain behaviour of novice end-users in the information retrieval environment.

Another feature which may account for the speed with which experts can solve problems in their domain of expertise is that they may be using parallel (simultaneous) processing of information, whereas novices may use serial processing, tending laboriously to think through one problem solution at a time (Matlin, 1994).

Finally, experts tend to spend more time thinking about possible constraints to an initial problem state than do novices (Voss et al, 1983, in Matlin, 1994). Experts possess superior "metacognitive" skills to those of novices; for example, they are much better at monitoring their own problem-solving processes, and are more aware than novices of when they might be making an error (Glaser & Chi, 1988, in Matlin, 1994).

When a novice in any field begins to learn a new concept, initially they use much conscious effort; this takes up much of the mind’s "working memory". As expertise increases, the effect of knowledge compilation means that thinking on that topic becomes increasingly automaticised, thus freeing working memory for the contemplation of new knowledge. For example, when one is learning to drive a car, all attention is focused on changing gears, steering, and so on (Gagne, Yekovich & Yekovich, 1993). With practice a production sequence for driving under normal conditions is automaticised; conscious thought is then available to monitor other variables, such as heavy traffic or rain.
In the context of performing a search, a novice end-user must concentrate on remembering the steps necessary to conduct a basic, successful search. As such a procedure is not yet automatic, the searcher’s mind is not free to consider optimal search strategies.

4.1.2 Information Processing Model

In the previous section, two types of knowledge representation - declarative and procedural - were described. Models of information retrieval from human memory can be developed for each of these types of knowledge.

A neural-network model, for example, can be used to represent the processing of a concept-based (declarative) problem (Marshall, 1990 in Gagne, Yekovich & Yekovich, 1993:12).

Procedural knowledge retrieval on the other hand, is well-suited to an information-processing model (Newell & Simon, 1972 in Gagne, Yekovich & Yekovich, 1993). An information-processing model represents information that is either controlled or automated; sequential; and iterative. The information-processing model caters for the production sequence of a procedure, characterised by IF ... THEN decision points.

These two models serve to illuminate the problem-solving process that must be executed by end-users when retrieving information from electronic databases. The models, adapted by the researcher to the information retrieval context, will be discussed in Chapter 5 of this thesis.

4.1.3 Information Processing and Problem Solving

A problem exists “when a living organism has a goal, but does not know how this goal is to be reached” (Duncker, 1945 in Garnham & Oakhill, 1994:200). The information retrieval process, for example, can be thought of
in information processing terms as a *problem space*, which comprises an initial state (the search question), a goal state (search results), and some kind of route, or series of processes (problem-solving heuristic), to get from the initial, to the goal, problem state (Newell & Simon, 1972 in Anderson, 1985). Further, the series of processes, or *operators*, will need to be functional within certain applicable *constraints* (Holyoak, in Osherson & Smith, eds, 1990). Such constraints could be time, or practicality, or availability of resources.

In order for a problem to be solved, it must first be represented in the memory in some way. This requires the construction of some kind of model of the problem in working memory; this model can be propositional, or analogical; it is then compared with existing representations in long term memory (Schunk, 1991). The problem can also be represented on paper, or on a whiteboard. There is increasing interest in the use of “mind maps” to facilitate problem definition; for example, Humeston’s study (1994).

Mind maps, or “concept maps” have been suggested as being useful for end-user education, as librarians strive to deliver effective instruction that encourages critical thinking, synthesis, evaluation, and retention of knowledge. Concept maps can be useful in that they can reveal an end-user’s misconceptions, or confirm the knowledge they do possess (Sherrat & Schlabach, 1990). Concept maps have been used also to assist in the construction of knowledge bases for “expert” computer systems (Smith, Krawczak, Shute & Chignell, 1987).

If a problem is not accurately represented, it will not be matched to the appropriate problem-solving routine(s), and a correct solution path will not be chosen (Chi & Glaser, 1985 in Schunk, 1991). Here again is a clear difference between novice and expert performance. As Schunk (1991:193) observed, “no matter how clearly solvers subsequently reason, they will not reach a correct solution unless they form a new representation”. This is
exactly one of the problems that the researcher observed, which triggered the current research: second year students were often unable to identify key words to conduct information searches on electronic databases.

4.2 Learning Theory

In the previous section of this chapter, a cognitive psychology framework for understanding the information retrieval process was described. In this section, cognitive learning theories, which are concerned with determining the most effective method of teaching (Jacobson & Jacobson, 1993), are discussed.

Jacobson & Jacobson (1993) outlined a very practical online searching instructional program based on a combination of several cognitive learning theories; however, they did not report on its efficacy. The instructional program arose as a result of Jacobson & Jacobson's observations of high school students. These observations suggested the possibility that too much choice in databases creates anxiety, and that the full range of possibilities available to searchers are not investigated because of the lack of an apparent easy route to discover them.

Further, Jacobson & Jacobson (1993) suggested that decontextualised knowledge (that is, knowledge without some framework with which to orient it) is inert (not taken up and used). They proposed that bibliographic instruction should use a conceptual framework, which might enable knowledge to become useful, rather than remaining inert.

Jacobson & Jacobson (1993) observed that it is "generally agreed" that students should receive an overview of the conceptual foundation for information retrieval, rather than merely instruction in the use of specific tools or protocols. Harter (1989, Jacobson & Jacobson, 1993) maintained that online searching instruction tends to put too much emphasis on the
acquisition of rules, which are relatively easy to teach, and too little emphasis
on the acquisition of heuristics, the strategies or tactics that experts typically
employ in solving online searching problems in the real world.

Jacobson & Jacobson (1993) suggested that recent cognitive learning theory
and research may help to address the problem of students only receiving
limited rule-based knowledge. They discussed three representative cognitive
theories of learning: Transforming Mental Models; Cognitive Flexibility
Theory; and Situated Cognition. These theories are described below.

4.2.1 Transforming Mental Models
White & Frederiksen (1986, in Glaser, 1990:35) viewed learning as “a process
of model transformation ... a progression through increasingly more
sophisticated mental models, each more adequate for a larger set of
problems.” This theory postulates that students assimilate new concepts by
modifying their existing “mental models”.

Borgman (1983a,b; 1989) discussed the efficacy of mental models and
conceptual frameworks in bibliographic instruction. In 1996, she proposed
that end-users require three layers of knowledge in order to be effective
searchers: conceptual (translating the information need into a suitable query
form); semantic (an understanding of the meaning of computing tasks and
concepts); and technical (basic computing skills). Borgman concluded that
conceptual skills are too often neglected in bibliographic instruction.

Experts employ multiple models when reasoning in complex domains. The
major learning mechanism postulated in this theory involves a process of
transforming the learner’s mental models about the content area. Novices in
a domain possess disconnected models of the content area; as knowledge
increases, these models change and become increasingly interconnected.
Further, novices tend to scan the surface features of a problem; experts
identify principles and make inferences that are quite apart from the surface features. As Glaser (1990:33) observed, "the preeminence of expert pattern recognition is such that the expert virtually sees a different problem from the one the novice sees".

The process of model transformation assumes that students must frequently restructure previously acquired knowledge to successfully understand a higher order model.

Another central component of this theory is that the learning environment should allow students to engage in a variety of learning strategies, such as open-ended exploration, problem-driven learning, example-driven learning, and student-directed learning. Kolb (1984) described the acquisition of skills through such active participatory means as discussion and problem solving. His theory of experiential learning assumes that ideas are formed and reformed through experience.

4.2.2 Cognitive Flexibility Theory

A shift from single to multiple knowledge representations, and from generic schema retrieval to situation-specific "knowledge assembly" is described in this theory (Spiro, Coulson, Feltovich & Anderson, 1988:382). The web-like nature of knowledge is stressed, and it is suggested that abstract concepts should be linked to case examples to enhance learning. Spiro et al (1988) suggested that complexity should be introduced sooner rather than later in the teaching framework to avoid students developing concepts that are too rigid, narrow or simplistic.

According to Spiro et al (1988), the period between initial learning and the achievement of practiced expertise, has not been studied extensively. Cognitive flexibility theory refers to this period as a stage of advanced knowledge acquisition, or advanced stage learning. Spiro et al (1988)
suggested that during this period, learners of complex knowledge frequently
develop serious conceptual misunderstandings and have difficulty in
transferring their knowledge to new situations. Further, they suggested that
the oversimplification of complex knowledge on the part of instructors and
learners is a significant factor contributing to the pattern of learning failure
identified in the stage of advanced knowledge acquisition.

Cognitive flexibility theory proposes several instructional guidelines to
overcome the tendency to present complex content in overly simplified
ways: using multiple knowledge representations such as analogies, case
examples, or lines of argument; explicitly linking abstract concepts to case
examples; stressing the interrelated and web-like nature of knowledge
(rather than compartmentalising it); early introduction to complexity in small
cognitively manageable units; and promoting knowledge assembly from
various previously learned components (rather than stressing the intact
recall of memorised information). Some of these guidelines have been
incorporated into the design of the modules used in the current research.

4.2.3 Situated Cognition
The third cognitive learning theory of relevance is known as "situated
cognition". Techniques such as collaborative and social learning are explored
in this framework. The concept of "cognitive apprenticeship" (where student
learning is analogous to the craftsman's apprentice) is another feature of the
theory - a student is "enculturated" through activity and social interaction in
a manner similar to the craft apprenticeship (Brown, Collings & Duguid,

The assumption that problems are context-specific, or "situated", is central to
the theory (Jonassen, 1997). It follows that if a concept is taught in a
"situated" context, learning will be enhanced. Situated cognition suggests
that knowledge is an entity that is developed and learned within a social context, and it is that context itself that shapes cognition.

Situated cognition is similar to Bandura’s concept of social learning, whereby “people are neither driven by inner forces nor buffeted by environmental stimuli. Rather, psychological functioning is explained in terms of a continuous reciprocal interaction of personal and environmental determinants” (Bandura, 1977:11-12).

Two instructional methods are suggested by the situated cognition framework: firstly, the “cognitive apprenticeship” approach, formulated by Collins et al (1989, in Chee, 1995), in which the concept is taught using the stages of modelling, coaching, scaffolding and fading. First, instructors model the concept by demonstrating strategies. Then they coach or provide scaffolding - some kind of structured support - to enable students to perform the task. Finally, they fade, or step back, as students become more capable and independent. This approach is “directed at teaching processes that experts use to handle complex tasks” (Chee, 1995:137). The expert approach is exemplified and situated in the context of its use. Again, the efficacy of modelling in the learning process had previously been discussed by Bandura; as he observed, “fortunately most human behaviour is learned observationally through modelling: from observing others one forms an idea of how new behaviours are performed, and on later occasions this coded information serves as a guide for action” (1977:22).

The second instruction method suggested by the situated cognition framework is the “collaborative learning” approach. Collaborative learning suggests that opportunities be provided for students to become involved in social interactions that help support the learning process (Cognition & Technology Group at Vanderbilt, 1990). For example, Cook, Kunkel & Weaver (1995) have conducted research into the relative merits of
collaborative learning and lecture formats in bibliographic instruction. They found that collaborative learning was not much more effective than traditional methods. However, they suggested that methodological problems (such as a lack of uniformity in the collaborative learning environments), could have contributed to this result, and suggested further research in the area.

Instructional principles derived from collaborative learning suggest that: collective problem solving may promote synergistic insights and solutions; group learning may allow students to confront ineffective strategies during discussions; and valuable collaborative work skills may be acquired.

Glaser (1990) suggested that a mix of cognitive instructional principles may prove to be optimal in the development of competent performance in a given task. Jacobson & Jacobson (1993) proposed that instruction based on a synthesis of the theories discussed above - transforming mental models, cognitive flexibility and situated cognition - should help students to develop the complex problem-solving abilities necessary to participate in the imprecise art of searching for information. The modules designed by the researcher for the current study incorporated elements of these theories as far as possible, in order to maximise learning within the time available.

4.3 Developmental Theory

The final area of cognitive psychology that serves to illuminate the information retrieval process is that of cognitive developmental theory. This area of research has developed only since the 1920s, and concerns the ways in which thinking processes change and develop over time.

Two main perspectives have influenced the study of cognitive development: maturationism, and empiricism. Maturationists, for example, Gesell (1929, cited by Kuhn in Bornstein & Lamb, eds, 1992), assert that cognitive
development is the result of an internal, pre-determined pattern that is unaffected by environment. However, failure of maturationists to account for the impact of the environment on behaviours led to the development of empiricism. Empiricists believe that cognitive development is externally derived, arising from the impact of environmental factors on the individual. The study of behaviourism, and the work of B.F. Skinner, arose from the empiricist school.

The empiricist school also led to the concept of reductionism; the notion that any complex behaviour is in fact a series of simple behaviours. A corollary of reductionism is parsimony; the view that the most simple explanation for an event is preferred over a complex one. In the case of cognitive development, this led empiricists to assert that there is no need for a theory of cognitive development; rather, that behaviour can be viewed as being comprised of a series of learning events, brought about through conditioning; cognitive development is therefore nothing more than a series of responses brought about by environmental action. (Kuhn, in Bornstein & Lamb, eds, 1992).

As neither maturationism nor empiricism were theories capable of explaining the complexities of cognitive development, interest turned to a constructivist approach - the most famous proponent of which was Piaget. Piaget believed that cognitive development resulted from an interplay of individual and environment; a gradual unfolding of increasingly sophisticated mental structures which narrowed the gap between mind and reality through a series of exchanges between the individual and the environment. As Kuhn (in Bornstein & Lamb, eds, 1992: 224) observed, the constructivist "posits a bidirectional interaction between individual and environment".

There is little research into the nature of cognitive development beyond adolescence, although as Kuhn (in Bornstein & Lamb, eds, 1992: 262)
observed, "if a major goal is to understand the range, the modifiability, the plasticity of adult cognitive functioning, a developmental framework may be, if not essential, at least extremely illuminating: in what directions and toward what ends does adults' cognitive functioning develop?" Another researcher whose work is of importance in this area is William Perry, who considered cognitive developmental levels in adolescents.

Key elements of the theories of Piaget and Perry are discussed in the next two sub-sections.

4.3.1 Piaget

According to Piaget (1952, in Mellon & Sass, 1981), all individuals pass through sequential stages of cognitive development. Each stage is characterised by a number of reasoning abilities; these abilities become more complex as the individual progresses through the sequence. The earlier stages described by Piaget concern young children; however the two most advanced stages - concrete operations, and formal operations - may still be observed in adolescents and young adults. Those people who could be described as "concrete" are only able to think logically about those situations or experiences with which they are very familiar. Students functioning on this level can follow instructions, as long as each component of the instructions is clear. Reasoning at this level tends to be unsystematic. Abstract ideas are difficult for the concrete reasoner to grasp.

If an individual progresses to the level of formal thinking, hypothetical situations and theories are able to be dealt with, and the necessity of taking into account all known variables relating to an hypothesis is recognised. Further, formal thinkers are able to analyse their own thinking patterns (Mellon & Sass, 1981). This ability is known as metacognition, and is a characteristic of expert cognitive behaviour. As Schell & Hall (1979:369) observed, "formal thought is a generalised orientation toward problem
solving that involves isolating elements of a problem and systematically exploring all the possible solutions”.

Even though the lower stage of cognitive development, concrete operations, seems to be universal, the stage of formal operations, in which it is possible to reason from hypotheses, is neither universal nor inevitable. Although not arrived at inevitably, formal thought is more likely to be present in societies where schooling is available, possibly because training in written language causes a child to separate thought from objects (Greenfield & Bruner, 1966 in Schell & Hall, 1979), and in adolescents from middle- and upper-middle-class backgrounds as opposed to those from lower-class backgrounds in western societies (Dulit, 1972 in Schell & Hall, 1979).

Factors to be considered in Piagetian developmental levels are summarised in Table 4-2 below.

Table 4-2: Thinking Strategies and Piagetian Developmental Levels

<table>
<thead>
<tr>
<th>Thinking strategies</th>
<th>Concrete Operations</th>
<th>Formal Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Abstract ideas</td>
<td>Not understood</td>
<td>Understood</td>
</tr>
<tr>
<td>2 Causal reasoning</td>
<td>Unsystematic</td>
<td>Systematic</td>
</tr>
<tr>
<td>3 Logical thinking possible in</td>
<td>Familiar situations</td>
<td>Unfamiliar situations</td>
</tr>
<tr>
<td>4 Can follow instructions which are</td>
<td>Clear</td>
<td>Unclear</td>
</tr>
<tr>
<td>5 Can reason from hypotheses</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>6 Recognise the need to take into account all known variables</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>7 Can analyse own thinking patterns</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
It would seem inappropriate therefore to assume that all university students (many of whom are under the age of 20) will be capable of formal thought in first year; some may never achieve it.

An important factor that appears to influence the transition from concrete to formal reasoning, according to Piaget, is self-regulation. Self-regulation refers to the process by which new information is examined, and an attempt is made to assimilate this new information into the existing cognitive framework. If the existing framework is not adequate, accommodation occurs. That is, reasoning patterns are altered to take into account the discrepant information. The processes of assimilation and accommodation have been taken up and incorporated into Perry’s theory of cognitive development in adolescents.

4.3.2 Perry

The Harvard psychologist, William Perry, is credited with having been the first to apply theories of cognitive maturation to college students and adults (King & Kitchener, 1994).

Perry described the progress of tertiary students from “dualistic” thinking, where information can be categorised as right or wrong; through “multiplicity”, where everyone has a right to his or her opinion; “relativism”, characterised by the phrase “it all depends”; and finally, “commitment”, or “full relevance”, where students realise the logical necessity to make choices based on evidence (Perry, 1968, 1981 in King & Kitchener, 1994, McNeer, 1991 and Mellon & Sass, 1981).

Cognitive developmental psychology has not been discussed extensively in the information retrieval literature, but two authors have suggested its relevance in this context. Oberman (1991) suggested that critical thinking is the most important element in bibliographic instruction. She discussed
Piagetian cognitive levels and noted that formal/abstract thinking - the developmental level necessary for critical thinking - should not be assumed, even at tertiary level.

McNeer (1991) suggested that a student's stage of cognitive development is an important consideration in planning bibliographic instruction. She observed that although librarians have in the past used trial and error to realize that, say, first year students are cognitively not as mature as graduate students, there is a need for bibliographic instruction programs that address more evenly the needs of these groups. McNeer used the example of first-year students, who tend to be literal minded; they want to know "the right answer". This type of reasoning corresponds to Perry's level of "dualistic" thinking. McNeer observed that graduate students, on the other hand, are able to transfer knowledge and strategies from one field to another. They are representative of Perry's more complex "relativistic" level of thinking.

McNeer (1991) recommended that, when suggesting a library assignment for a course, the developmental level of the students involved should be considered, and instruction should be designed to facilitate movement to the next developmental level.

In designing the Module for Stage 1 of the current study, the researcher attempted to address the process of self-regulation (which is suggested by Piaget and Perry as facilitating the change from a concrete to a formal level of thinking) by incorporating instructional elements which would support the process. For example, when describing electronic databases and their capabilities, a number of analogies were used. Cognitive psychology suggests that analogies may help students to develop more complex mental models of a concept. In terms of developmental psychology, the use of analogies may enable existing, possibly limited, concepts of electronic databases to be expanded. The process of introducing new perspectives not
subsumable into existing mental models, may assist in the development of a more sophisticated representation, or mental model, of electronic databases. In other words, a change from concrete to formal reasoning may be encouraged.

4.4 Conclusion
In this chapter, three key areas of cognitive psychology have been discussed. The first, information processing theory, explores the nature of knowledge representation and problem solving. These theories provide an explanation of the information retrieval, or search, process.

The second branch of cognitive psychology discussed, cognitive learning theory, is valuable in that it suggests practical teaching tools for the development of conceptual skills in students. Conceptual understanding of the information retrieval process has been identified by some authors as being central to information retrieval success.

Finally, cognitive developmental psychology provides one possible explanation for the significant variation in information retrieval success which has been reported by many researchers in the field of information retrieval instruction.

That fact that information retrieval is a complex problem-solving process is undisputed. As Borgman (1986:397) observed, “information retrieval behaviour appears to be determined by a number of factors, including training, experience, system features, the nature of the search topic, and individual characteristics.” In the researcher’s view, the complexity of the process has been overlooked in many of the studies which have been conducted to determine the most beneficial means of teaching information retrieval to novice end-users. A few researchers, however, have commented on the need to develop courses in information retrieval which incorporate...
the teaching of concepts of retrieval, rather than simply focussing on the teaching of the mechanics of database operation.

On the topic of higher education generally, it has been suggested that significant benefits in teaching and learning may be achieved through the combination of cognitive developmental theory, individual differences, and learning theory (Demetriou, Platsidou, Efklides, Metallidou & Shayer, 1991).

The present study attempts such integration, in the context of information retrieval. In the following chapter, the integrated theoretical structure is described.
5. THEORETICAL FRAMEWORK

5.1 Introduction

In the previous two chapters, information retrieval literature was reviewed, and the efficacy of cognitive psychology in understanding, modeling and teaching the information retrieval process was discussed. In this chapter, these issues are brought together in the theoretical framework specific to this study. This framework takes into account the work done by previous researchers in modeling of the information retrieval process, reviewed in chapter 3. In section 5.2, a two-stage model of the information retrieval process is proposed. In section 5.3, learning theories that underpin the teaching strategies developed for this study are outlined. In section 5.4, the role of critical thinking in the information retrieval process is discussed; in section 5.5, a framework for the teaching of information literacy in general is suggested. In sections 5.6 and 5.7, research questions and hypotheses for Phase 1 of the study are described; and a summary of the chapter is provided in section 5.8.

5.2 The Search Process and Information Processing Models

In Chapter 4, two types of knowledge representation in human memory were discussed. The first was declarative - knowledge of concepts and facts. The second was procedural - knowledge of a series of steps that can be used to negotiate a "problem space" from an "initial state" to a "goal state", or problem solution.

In information processing terms, the researcher suggests that information retrieval from electronic databases can be represented usefully as a two-stage process. The first stage involves problem recognition. At this stage, the end-user is presented with a problem - for example, an essay question. The end-user has to analyse the problem and identify and categorise issues suggested by that problem, before a search can be implemented. Problem recognition involves the end-user searching his or her existing mental models, or schema
that is, declarative knowledge - for a concept or concepts that match the problem(s) represented in the essay question.

In information processing, the neural network model of information retrieval (Marshall, 1990, in Gagne, Yekovich & Yekovich, 1993) suggests that information retrieval from declarative knowledge is simultaneous and unconscious. That is, when the end-user engages in problem recognition, the process is largely unconscious and the declarative knowledge “database” is scanned simultaneously, rather in the way that access by a computer to information stored on a CD-ROM is random, rather than sequential, as it would be on a reel to reel tape or cassette. This representation aids in the description and understanding of the way end-users must examine their declarative knowledge in order to be able to understand and interpret the research question with which they have been presented.

Perhaps more importantly, it also explains why end-users, when confronted with the same search question, will use a range of keywords and search terms for searching - the naming and labelling problems mentioned by many researchers (Saracevic, 1991; Iivonen, 1995; Chen & Dhar, 1991; Ehrlich & Cash, 1994a). As each end-user’s network of schemas is unique, the language used by each end-user to represent those concepts is unique. In the researcher’s view, an understanding of the processes of declarative knowledge storage and retrieval provides an explanation for the “intriguing vagaries” in human behaviour evident in an information search (Wallace, 1993:239), and also goes some way to addressing the lack of theoretical underpinning for search strategy formulation discussed by Lancaster et al (1994:374):

Although much has been written on the subject of search strategy, little real research has been done on how different people arrive at alternative search approaches for the same research problem. Even Saracevic et al [1988], while they reported significant differences in approaches, did not try to explain why these differences occur.
Networks (schema) of the concept(s) contained in the essay question must be searched. Cognitive psychology suggests that when networks in long-term memory that fit the problem are found (in other words, patterns are recognised), the pattern with the highest level of activation (i.e., the best fit with the problem question) will be selected. If the schema, or pattern, is inadequate for the problem to be understood, the end-user will have difficulty solving the problem. For example, they will not be able to identify concepts essential to the understanding of the search problem, and to generate appropriate search terms and strategies for effective information retrieval from an electronic database.

Further, Piette, (1995, in Martin, ed, 1995:81) outlined Gagne & Merrill’s (1990) concept of the “enterprise schema”, which implies that in order for successful understanding and performance in a given domain, “the learner must acquire not just one skill or concept but an entire ‘enterprise schema’”. This necessitates instruction that involves a combination of conceptual and procedural skills.

Figure 5-1 is suggested by the researcher as an illustration of the first stage of the information retrieval process - problem identification; in this case, essay question interpretation. The word “interpretation” is used, as problem identification will depend on the completeness and accuracy of the mental models of a particular end-user, and on their own unique “tangled network” configuration.
Figure 5-1: Information Retrieval - Stage 1:
Neural Network Model of Question Interpretation

INPUT: Should we clone humans?

OUTPUT: Ethics question

(adapted from Marshall, 1990 in Gagne, Yekovich & Yekovich, 1993)

The question “Should we clone humans?” is used as an example of a search query that necessitates interpretation by the end-user in order to identify both explicit, and implied, search terms that would aid in the achievement of an effective search outcome. Using the information processing model, input to memory is the search question “Should we clone humans?”. This “input” is represented in working memory as a mental model, or schema, that is then unconsciously compared to a number of schemas in long term memory simultaneously.
When the closest “match” is found, the subject’s output response (question interpretation) could be medicine, ethics, etc. Those people with the most accurate schemas (mental models) would infer correctly that “should” means “ethics”, even though that concept is not explicitly included in the question.

Once the problem has been “recognised”, the second stage of the information retrieval process is “running” the search, which involves formulating search strategies, conducting the search, and evaluating information found. If the problem has been inadequately recognised or interpreted, this second stage is unlikely to be successful, even if it is correctly executed. The iterative nature of the second stage may however result in the problem later being correctly “recognised”, due to new input that changes the original schema. This is compatible with Ingwerson’s view (1992, in Bystrom & Jarvelin, 1995:191); that is, the cognitive view on information interaction that “potential information gained from information systems may transform the information user’s knowledge structures”. It is also compatible with Kuhlthau’s (1988,1994) “constructivist” view that the search process takes into account the modification of ideas as new information is encountered; Marchionini’s (1995) description of information seeking as a series of iterative sub-processes; and Spink’s (1997) discussion of the importance of feedback loops.

Newell & Simon’s standard information processing model (1972, in Gagne, Yekovich & Yekovich, 1993) has been adapted by the researcher to represent this process (Figure 5-2).
The information processing model when applied to information retrieval suggests that after the problem has been identified; that is, the concepts central to the search question have been isolated, the end-user will then go through an iterative search process, or production, that is characterised by a number of sequential operations and IF ... THEN decision points. This process may be either partially automated (as in the case of an expert searcher), or conscious (as in the case of a novice searcher). Each decision point represents a point at which the direction of the search may be changed. Examples of
questions asked at decision points are: “Do I have a clear understanding of what the question means?” “Have I identified all keywords”? “Have I chosen the right databases?” “Is the information I have found useful?” At this last decision point, if information is judged as not useful, the question is reviewed and the search is reformulated and repeated on the same, or different, databases.

It is suggested that instruction based on elements of learning theory will be of assistance in both the first stage of the information retrieval process - identification of the question; and in the second stage of the process - the database search itself.

5.3 Type of Instruction

Research reviewed in Chapters 3 and 4 suggests two key points regarding information retrieval instruction. Firstly, many studies to date which have examined the relative efficacy of teaching methods have compared only methods of skills instruction, for example, “hands on” instruction, or demonstration (Ramaoka, 1995; Davis & Bostrom, 1993). These studies have had mixed results. Secondly, a number of studies, also with mixed results, have suggested that information retrieval requires conceptual knowledge and problem-solving ability, as well as skills training in the mechanics of database operation.

In order to test the efficacy of concept-based instruction, and the utility of demonstrating a problem-solving heuristic rather than merely demonstrating the online search process, the researcher combined elements of the three learning theories discussed by Jacobson & Jacobson (1993), in the design of the teaching modules used in the present study. The first learning theory is transforming mental models. In the context of information retrieval, this theory suggests that most first-year undergraduate students have some kind of mental model of how to search for information by, for example, looking up a book, or a library catalogue. This model has to be transformed if the student
is to search effectively using computer databases. The new model has to take into account how search techniques need to be adapted to other databases, or for example, the internet. A variety of teaching strategies are suggested by this theory: open-ended exploration; problem-driven learning; example-driven learning; and student-directed learning. A number of these strategies are incorporated into the Module designed by the researcher for Phase 1 of this research, and again in the series of Modules designed for Phase 2.

The second learning theory is situated cognition. This theory suggests that at the stage of learning between beginners and experts, oversimplification of complex knowledge can be a significant factor contributing to patterns of learning failure in advanced knowledge acquisition. This approach is supported by Gagne, Yekovich & Yekovich (1993), who discuss the importance in schema formation of the use of many examples of the information being taught, varying on irrelevant detail. These theories suggest therefore that the information retrieval process, which is complex, should not be oversimplified. Teaching strategies include the use of analogies and case examples, the stressing of the inter-relationship of knowledge, early introduction of complexity, and the promotion of knowledge assembly. Again, these elements are incorporated into the teaching Modules designed and implemented in Phases 1 and 2 of this research.

Finally, the theory of situated cognition suggests that knowledge is developed and learned through example, in a social context. The instructional method of cognitive apprenticeship is adapted in the Modules: a problem-solving heuristic is modelled; and students are coached in its correct application.

The purpose of the Module designed for Phase 1 was to develop a conceptual knowledge of information retrieval in novice searchers. Penhale & Taylor (1986, in Jacobson & Jacobson, 1993), observed that expert searchers display more citations, review more search sets, enter more search terms, adjust their search strategies more often, and change databases more often, than do
novices. In the current study, the researcher used these criteria, and others, to measure search performance.

Further, developmental psychology suggests that using analogies in teaching will support change from concrete to formal operations because they help develop more complex mental models, which may in turn, through self-regulation, foster the development of complex and accurate models of the information retrieval process.

5.4 Thinking Processes
In the previous sections, a two-stage model of the information retrieval process has been described. Teaching strategies designed to facilitate information retrieval capabilities as described in that model, have been discussed.

The model is not complete however. The researcher is of the view that other components of information literacy - critical thinking - are essential to successful information retrieval. These issues were discussed in Chapter 2. Other researchers, for example, Marchionini (1995), have discussed the role of ongoing judgment in the iterative information seeking process. Wilson (1998) has discussed the importance of a problem-solving conceptualisation of the process. The researcher is of the view that each stage of the search process is driven by a range of critical thinking skills. These skills can be taught; however, the teaching of these skills was beyond the purview of Phase 1 of this study. Phase 2 - the broadening of skills taught to include critical thinking skills - was conceptualised as being an important development and extension of the hypotheses being tested in Phase 1, but its precise design was contingent on the results of Phase 1.
5.5 Framework for the Teaching of Information Literacy

The two-stage model of the information retrieval process described above is an attempt to extend knowledge of that process. The teaching strategies and content of the Modules designed for Phases 1 and 2 of this study have been developed with the elements of that model in mind.

The significance of such a model, and the importance of effective teaching and learning strategies for information retrieval, is not apparent until these elements are situated in the wider environment of information literacy - an essential body of knowledge for engagement with an information-driven society.

The researcher is of the view that a framework for the conceptualisation and teaching of information literacy may have considerable utility at any educational level, given the importance of that cluster of knowledge and skills in modern society. The researcher suggests further that the three central components of such a framework comprise: locating; analysing; and articulating the value of information. Each of these central components subsumes a cluster of conceptual and procedural knowledge and critical thinking skills. Each component is usefully supported by end-user computing capabilities. This framework for the teaching of information literacy is described in detail in Chapter 12.

Returning to Phase 1 of this study, research questions and hypotheses relating to the teaching of information retrieval are described in the next section.

5.6 Phase 1 Hypotheses

In this section, research questions for Phase 1 suggested by the literature reviewed in Chapters 3 and 4, are posed. Hypotheses stemming from these questions are formulated.
5.6.1 Research Question 1

Literature on the efficacy of concept-based instruction, as opposed to skills-based instruction, for information retrieval is not extensive; results are not always consistent (Balaraman, 1991; Oberman, 1991; Sein & Bostrom, 1989 in Balaraman, 1991). The first research question was therefore:

**Research question 1:** will type of instruction influence acquisition of knowledge of electronic database searching?

Literature suggests that only 12.5% of 595 studies conducted on bibliographic instruction in the last 20 years have been experimental (Edwards, 1994). In order to enable statistical analysis of results from the current study, a pre-test - post-test experimental design, with random assignment to experimental and control treatments, was used. In order to enable empirically rigorous testing of research question 1, hypotheses tested were:

*Hypothesis 1a:* There is a difference between experimental and control groups on electronic database knowledge in the pre-test.

The pre-test (Survey 1, section 2) comprised a number of multiple-choice questions designed to establish baseline information on knowledge of electronic databases.

*Hypothesis 1a (null):* There is no difference between experimental and control groups on electronic database knowledge in the pre-test.

If hypothesis 1a (null) was able to be accepted, it could be concluded that there was no difference between experimental and control groups on electronic database knowledge.

*Hypothesis 1b:* There is a difference between experimental and control groups on electronic database knowledge in post-test 1.
Post-test 1 (Survey 2, Section 2) comprised a similar battery of multiple-choice electronic database knowledge questions as those used in the pre-test.

\textit{Hypothesis 1b (null)}: There is no difference between experimental and control groups on electronic database knowledge in post-test 1.

If hypothesis 1b (null) was able to be rejected, provided that intervening variables are controlled, it could be concluded that the experimental treatment influenced subjects' knowledge of electronic database searching.

5.6.2 \textit{Research Question 2}

The researcher suggests that a change in electronic database knowledge does not translate necessarily into more effective search strategies and results. The second research question was:

\textit{Research question 2}: \textit{will type of instruction influence information retrieval effectiveness?}

Previous studies have measured instruction effectiveness by such means as improved knowledge of terms only (Reddy, 1988), and precision and recall. One, Zahner (1992) has used an experimental design to measure differences in "research process orientation" as a function of library instruction. In that study, subjects completed a bibliography on a given question. The researcher proposes to use an Information Retrieval Assignment (post-test 2) to enable the measurement of the effectiveness of the type of instruction used in terms of search strategy formulation and search results. Three search topics of varying difficulty will be used, in order to enable determination of differences in search behaviour, depending on degree of search difficulty.

\textit{Hypothesis 2}: There is a difference between experimental and control groups on search performance.
Search performance was measured by post-test 2: Information Retrieval Assignment.

*Hypothesis 2 (null):* There is no difference between experimental and control groups on search performance.

If hypothesis 2 (null) was able to be rejected, it could be concluded that the experimental instruction influenced search outcome.

**5.6.3 Research Question 3**

Literature suggests a number of human factors that may influence information retrieval effectiveness (Borgman 1986, 1989; Saracevic & Kantor, 1988). Problem-solving ability is one of these. Eisenberg & Small (1993) suggested the broadening of learning outcomes in information retrieval to include information problem-solving skills; yet there is little empirical evidence to confirm or deny its role in the information retrieval process. Research question 3 was therefore:

**Research question 3:** *Are problem-solving ability and information retrieval effectiveness related?*

To enable any link to be identified between problem-solving ability and information retrieval, problem-solving ability has to be measured. On the pre-test administered to all subjects prior to the experimental treatment, a series of questions designed to measure aspects of problem-solving ability was included.

*Hypothesis 3:* There is a difference in search performance depending on problem-solving ability.

*Hypothesis 3 (null):* There is no difference in search performance depending on problem-solving ability.
If hypothesis 3 (null) was able to be rejected, then the conclusion could be drawn that problem-solving ability affected information retrieval.

5.7 Phase 1 Other Correlates

5.7.1 Cognitive Maturity

Literature suggests that cognitive maturity may affect students' ability to think hypothetically, and to understand and execute problem-solving routines (Marini & Case, 1994). Kuhlthau (1994) has suggested that effective searching involves Piaget's "formal" level of cognitive operations; Limberg (1999) has observed a similarity between poor search performance and Perry's "dualistic" stage of cognitive maturity. Accordingly, research question 4 was:

**Research question 4:** Are problem-solving ability and cognitive maturity related?

Any relationship between problem solving and cognitive maturity cannot be inferred without measurement of both being made. In addition to electronic database knowledge (pre-test, Section 2) and problem solving ability (pre-test, Section 3), cognitive maturity was assessed in the pre-test (Section 4). The researcher notes that research question 4 was not the main focus of the study, and that in the interests of enabling adequate testing of the essential components - electronic database knowledge and problem-solving ability - Section 4 was designed to be exploratory in nature. A further difficulty in testing cognitive maturity in young adults is the lack of reliable instruments available for that purpose.

**Hypothesis 4:** There is a relationship between problem-solving ability and cognitive maturity.

**Hypothesis 4 (null):** There is no relationship between problem-solving ability and cognitive maturity.
If hypothesis 4 (null) was able to be rejected, a tentative conclusion could be drawn that there is a relationship between problem-solving ability and cognitive maturity.

5.7.2 Pattern Recognition

Information processing theory suggests that pattern recognition in experts is far better than that of novices, who typically waste time on irrelevant information. Pattern recognition refers to the ability of a subject to identify relevant patterns, or relationships, in a given situation. Research question 5 was therefore:

**Research question 5:** Are there any differences in the search behaviour of more effective and less effective searchers?

In the information retrieval context, pattern recognition might be suggested by a subject's search strategy formulation. The number and type of concepts used to characterise the research question; the type of database(s) selected, and the type of search strategies, could all indicate differences between pattern recognition in good searchers, and in poor searchers. In this context, "good" searchers were those who rated "adequate", "good" or "superior" on the Search Success variable. The hypothesis suggested by research question 5 was:

*Hypothesis 5:* Good searchers identify more concepts, use a greater number of relevant databases, and construct more effective search strategies, than do poor searchers.

*Hypothesis 5 (null):* Good searchers do not identify more concepts, use a greater number of relevant databases, and construct more effective search strategies, than do poor searchers.
If hypothesis 5 (null) was able to be rejected, the conclusion could be drawn that better searchers use more concepts, more databases that are relevant, and more effective search strategies, than do less effective searchers.

5.8 Summary

In this chapter, a theoretical framework for this research has been described. The framework comprises a two-stage model of the information retrieval process. In Phase 1 of this study, a single teaching Module based on learning theory paradigms tested both the efficacy of these teaching strategies, and the utility of the model. Phase 2 of the study comprises a series of Modules that incorporate another important aspect of information retrieval - critical thinking. The significance of the two-stage model, and the concept-based teaching strategies for information retrieval instruction, is seen when situated in the broader context of information literacy. A framework for the teaching of information literacy has been outlined, and is detailed in Chapter 12.

Five research questions have been proposed for Phase 1:

1. Will type of instruction influence acquisition of knowledge of electronic database searching?
2. Will type of instruction influence information retrieval effectiveness?
3. Are problem-solving ability and information retrieval effectiveness related?
4. Are problem-solving ability and cognitive maturity related?
5. Are there any differences in the search behaviour of more effective and less effective searchers?

In the next chapter, general methodological issues, and the Method for Phase 1, are discussed.
6. METHOD

6.1 Introduction

Ethical issues, assumptions and rationale for the selection of the research designs for Phases 1 and 2 are discussed in section 6.1 of this chapter. In section 6.2, the Phase 1 study is described; instruments used in that study are discussed in section 6.3. Issues in measurement are discussed in section 6.4; data analysis in section 6.5. Phase 2 method is described in Chapter 9.

6.1.1 Ethics

When dealing with human subjects, ethical issues are an important consideration in the conceptualisation and execution of research. Issues of confidentiality, privacy, anonymity and equity (between experimental and control subjects) were carefully considered in the design of this study. Both phases of the study were approved by the University of Canberra Committee for Ethics in Human Research after detailed written submissions on the proposed research had been provided.

Ethical considerations relating to this study are subsumed by the Privacy Act 1988 (Cth). Student ID numbers, names, or other information that would identify specific subjects was not requested. Instead, subjects identified themselves by means of “nicknames” known only to them. This allowed pre- and post-test data to be matched, whilst ensuring at the same time that the researcher did not know the identity of the subject. The only person handling data was the researcher, who undertook categorically to preserve the confidentiality of information of all subjects taking part in the research.

Further, statistical analyses were primarily on group results, not individual performance. Data were kept physically secure by storing all paper and electronic records in locked cabinets at the University.
Phase 1

In the first lecture for the unit in which the research was undertaken, the researcher advised the students that a research project was being undertaken, described the research, requested participation, and assured students of the confidentiality of their input.

Informed Consent was obtained (Appendix 1).

There was no disadvantage to students arising from the conduct, or non-conduct, of the experiment in the unit. The researcher (in consultation with the Lecturer in charge of the unit) was very careful to ensure that whilst experimental components were integrated into the design of the unit, no assessment weighting was attached to them. Moreover, experimental elements (CD-ROM instruction; instruction in problem solving and search techniques) contributed to the achievement of learning outcomes for the unit. After administration of the post-tests, the control group was given a detailed handout on the information retrieval techniques that had been taught to the experimental group, to ensure adherence to ethical research practices.

Phase 2

In the first lecture of first semester 1999, students in the subject Office Management 3/4 were given a talk that covered the aims, methodology and expected outcomes of the research (approximately 15 minutes). The time taken to conduct the research, and the level of involvement of participants, was discussed. They were told that participants would complete a 30 minute pre-test questionnaire, five 30 minute teaching modules, and a 30 minute post-test. Students were advised that there would be no adverse consequences from either participating, or not participating, in the study. Participation was entirely voluntary and anonymous. Students were given an Informed Consent form (Appendix 2) to take home and read. In the
second lecture (the following week). Informed Consent forms were collected from those students who decided to participate.

Those students who did not wish to participate (there was one) did not complete the pre-and post-tests, and did not need to attend the first half hour of the 90 minute tutorials in weeks 3-7, when the modules were taught.

The control group received skills-based training in information retrieval, whilst the experimental group received concept-based training. After completion of post-tests, the control group was taught the concept-based training, to ensure adherence to ethical research practices.

6.1.2 Assumptions

A number of assumptions have been made in the formulation of the theoretical framework for this study:

1. Information retrieval is a cognitive behaviour.
2. Certain cognitive behaviours – such as problem solving – can be learned.
3. Some teaching strategies (such as concept-based teaching) are more effective than other teaching strategies.
4. A cognitive maturation process exists.
5. A higher level of cognitive maturity is preferred over a lower level of cognitive maturity.
6. Critical thinking skills are involved in information retrieval.
7. Information retrieval is one of a sub-set of skills comprising information literacy.
8. Information literacy is underpinned by a range of critical thinking skills.
9. Information literacy is a desirable outcome of education.
These assumptions are discussed in the context in which they arise (Chapters 2 - 5).

6.1.3 Research Method

Research method needs to be both appropriate for, and feasible to, the testing of hypotheses under consideration (Sproull, 1995; Tague-Sutcliffe, 1992). A range of qualitative and quantitative methods was considered for the conduct of the study. The researcher is aware of the trend in information retrieval research towards qualitative data, for example, phenomenology, but felt that such a method was inappropriate for the aims of this study. The researcher was concerned with developing teaching and learning strategies to enhance information retrieval effectiveness, and wished to measure outcomes by means of observable participant output over an entire cohort. "Rich" data gathering on the thinking strategies employed by a small number of individual participants was therefore not appropriate. Further, in the light of the discussion of the paucity of rigorous quantitative designs in the information retrieval literature (see Chapter 3.4), a quantitative design was preferred.

The type of quantitative design achievable depended on a number of factors, including: the type of information desired; resources; the degree of control over selection (or more importantly, assignment) of subjects; and the ability to manipulate the independent variable (Sproull, 1995). When the researcher is able to exert control over all of these factors, as was the case with this study, a true experimental design is appropriate; accordingly, the design used for the current study was a pre-test/post-test control group experimental design, which is a very strong research design (Sproull, 1995). The strength of this design means that, provided that the study is conducted properly, a cause and effect relationship between the independent and the dependent variables can be discussed. This characteristic is unique to the experimental research design.
6.2 The Study - Phase 1

In this section, research design, population and sample, timetable, variables, issues relating to data collection, and limitations, are described. The method chosen for this study was 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 given a short teaching module, based on learning theory paradigms, in order to determine whether this concept-based instruction would result in subjects being able to conduct more successful searches than control group subjects.

Table 6-1 below summarises the hypotheses to be tested, stated in the null form, and the instruments that were used to enable measurement.

Table 6-1: Summary of Hypotheses (Null Form) and Instruments of Measurement

<table>
<thead>
<tr>
<th>Hypotheses (Null Form)</th>
<th>Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a There is no difference between experimental and control groups on electronic database knowledge in the pre-test</td>
<td>Survey 1, section 2: Electronic Database Knowledge (pre-test)</td>
</tr>
<tr>
<td>1b There is no difference between experimental and control groups on electronic database knowledge in post-test 1</td>
<td>Survey 2, section 2: Electronic Database Knowledge (post-test 1)</td>
</tr>
<tr>
<td>2 There is no difference between experimental and control groups on search performance</td>
<td>Information Retrieval Assignment (post-test 2)</td>
</tr>
<tr>
<td>3 There is no difference in search performance depending on problem-solving ability</td>
<td>Information Retrieval Assignment (post-test 2) and Survey 1, section 3: Problem-solving Ability</td>
</tr>
<tr>
<td>4 There is no relationship between problem-solving ability and cognitive maturity</td>
<td>Survey 1, section 3: Problem-solving Ability and Survey 1, section 4: Cognitive Maturity</td>
</tr>
<tr>
<td>5 Good searchers do not identify more concepts, use a greater number of relevant databases, and construct more effective search strategies, than do poor searchers</td>
<td>Information Retrieval Assignment (post-test 2)</td>
</tr>
</tbody>
</table>
6.2.1 Research Design

The experimental design for this research is summarised in Table 6-2.

Table 6-2: Experimental Design for Phase 1

<table>
<thead>
<tr>
<th>Pre-test</th>
<th>Treatment (independent variable)</th>
<th>Post-tests (dependent variables)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group</td>
<td>Standard test to measure knowledge of electronic databases and problem-solving skills (Survey 1)</td>
<td>Standard skills instruction in electronic database use (lecture 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental group</td>
<td>Standard test to measure knowledge of electronic databases and problem-solving skills (Survey 1)</td>
<td>Standard instruction (lecture 1) combined with instruction in electronic database concepts and problem solving (teaching module)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.2.2 Population and Sample

The experiment was conducted in 1997, during first semester at the University of Canberra, Australia. The researcher conducted the experiment with first year undergraduate subjects in order to determine the impact of teaching strategies on “novice” searchers. In order to control intervening variables, it was decided that the undergraduate cohort must meet a number of criteria:

1. Pre-test (Appendix 3) to be conducted during the first week of first semester, first year.
2. Experimental module to be run as soon as possible thereafter.
3. As large a sample size as possible.
4. Random assignment to treatment groups.
5. Technology to allow conduct of experiment must be available.
6. The experimental module must be integrated into a unit.
7. The post-test Information Retrieval Assignment (Appendix 4) must be relevant to the unit.
8. The post-test survey (Appendix 5) must be administered as soon as possible after the Information Retrieval Assignment is completed.

For the purposes of this study, 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 first year unit Communication Interface 1 at the University of Canberra. This unit was suitable because:

1. It was a large unit (up to 300 students are usually enrolled; at the beginning of first semester 1997 there were approximately 250 students 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, thereby reducing the impact of many of the intervening variables discussed in section 6.2.3.

2. It was a "service" unit. That is, it was a unit that draws students from all six faculties of the University of Canberra, and may have been expected to be reasonably representative of the population. In the actual sample, the faculties were not equally represented, however. The Faculty of Communication was the most highly represented, while the
Faculty of Environmental Design was unrepresented. Details of the sample are discussed in Chapter 7 - Results.

3. School leavers and mature-aged students were represented in the unit. Although school leavers with no previous knowledge of electronic databases were the subjects who would most likely reveal any change in knowledge of search behaviour as a function of type of instruction, it was expected that much useful data would be generated by the analysis of mature-aged student performance as well, both in providing comparative data, and in terms of allowing correlations between age and problem-solving ability and/or cognitive maturation to be explored.

4. The experiment as proposed could be integrated effectively with the learning outcomes for the unit, so ensuring that no student would be disadvantaged by having participated in the study.

5. The lecturer-in-charge of the unit had given her permission and support for the experiment to be conducted.

Tutorials were offered every weekday. There were 11 daytime tutorials (held between the hours of 8.30 am - 4.30 pm), and seven evening tutorials (starting at 4.30 pm or later); a total of 18 tutorials.

Table 6-3 shows the day and time of tutorials in the unit, whether the treatment was experimental or control, and the number of students in each tutorial. All 254 students enrolled in the unit gave their written consent to participate in the study.

Tutorials comprised (usually) a maximum number of 15 or 16 students, as each student required access to a computer. The tutorial groups were randomly assigned to either the experimental or the control groups (nine of
each) by putting all the tutorial numbers in a large tin, and then extracting them. The first nine tutorial numbers extracted from the tin comprised the experimental group. After random allocation to treatments, the experimental group consisted of five daytime and four evening tutorials. The control group comprised six daytime and three evening tutorials.

Even though this sample was a “convenience” sample (Sproull, 1995:119), in that it was a cohort of students already formed, the researcher considered that its parameters were such that it 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.

Table 6-3: Communication Interface 1, First Semester 1997 - Statistics

<table>
<thead>
<tr>
<th>Tutorial Number</th>
<th>Day</th>
<th>Start and Finish</th>
<th>Number of students participating in study</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Monday</td>
<td>1500-1630</td>
<td>15</td>
<td>Experimental</td>
</tr>
<tr>
<td>22</td>
<td>Monday</td>
<td>1500-1630</td>
<td>17</td>
<td>Control</td>
</tr>
<tr>
<td>23</td>
<td>Monday</td>
<td>1700-1830</td>
<td>11</td>
<td>Experimental</td>
</tr>
<tr>
<td>1</td>
<td>Tuesday</td>
<td>1030-1200</td>
<td>15</td>
<td>Control</td>
</tr>
<tr>
<td>3</td>
<td>Tuesday</td>
<td>1230-1400</td>
<td>16</td>
<td>Experimental</td>
</tr>
<tr>
<td>5</td>
<td>Tuesday</td>
<td>1630-1800</td>
<td>14</td>
<td>Control</td>
</tr>
<tr>
<td>6</td>
<td>Tuesday</td>
<td>1830-2000</td>
<td>12</td>
<td>Experimental</td>
</tr>
<tr>
<td>7</td>
<td>Wednesday</td>
<td>1030-1200</td>
<td>17</td>
<td>Experimental</td>
</tr>
<tr>
<td>8</td>
<td>Wednesday</td>
<td>1430-1600</td>
<td>12</td>
<td>Control</td>
</tr>
<tr>
<td>9</td>
<td>Wednesday</td>
<td>1430-1600</td>
<td>15</td>
<td>Experimental</td>
</tr>
<tr>
<td>12</td>
<td>Wednesday</td>
<td>1830-2000</td>
<td>15</td>
<td>Control</td>
</tr>
<tr>
<td>13</td>
<td>Thursday</td>
<td>0830-1000</td>
<td>15</td>
<td>Control</td>
</tr>
<tr>
<td>14</td>
<td>Thursday</td>
<td>1030-1200</td>
<td>15</td>
<td>Control</td>
</tr>
<tr>
<td>15</td>
<td>Thursday</td>
<td>1630-1800</td>
<td>12</td>
<td>Experimental</td>
</tr>
<tr>
<td>16</td>
<td>Thursday</td>
<td>1630-1800</td>
<td>15</td>
<td>Control</td>
</tr>
<tr>
<td>17</td>
<td>Thursday</td>
<td>1830-2000</td>
<td>13</td>
<td>Experimental</td>
</tr>
<tr>
<td>19</td>
<td>Friday</td>
<td>1030-1200</td>
<td>10</td>
<td>Experimental</td>
</tr>
<tr>
<td>20</td>
<td>Friday</td>
<td>1230-1400</td>
<td>15</td>
<td>Control</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>254</strong></td>
<td></td>
</tr>
</tbody>
</table>
6.2.3 Variables

The independent variable in Phase 1 of the study was the teaching Module (Appendix 6) designed to determine whether concept-based instruction (as opposed to skills-based instruction alone) will 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. These instruments are described in section 6.3 of this chapter.

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.

Other intervening variables for the Information Retrieval Assignment include guidance from academic and library staff, or help from friends. The researcher addressed these variables by firstly, allocating an appropriate assessment weighting to the Assignment. The researcher was of the view that to ensure the Assignment would be attempted, it had to have some role in the subject's successful completion of the unit Communication Interface 1. On the other hand, any actual assessment weighting would be inappropriate, as it was expected that subjects in the control group would not complete the Assignment as effectively as those in the experimental treatment. Further, if the Assignment had an actual assessment weighting, subjects might collaborate in its completion, in order to maximise their grade. The
researcher decided therefore to allocate a "Complete/Not Complete" criterion to the Assignment. That is, subjects were obliged to attempt the Assignment in order to fulfil assessment criteria for the unit, but were not allocated a grade for it.

With regard to information from academic or library staff about database searching, other than that obtained prior to the conduct of the experiment, or given as part of the experimental treatment, the researcher accounted for these intervening variables in a number of ways. Firstly, by keeping to a short time frame between the distribution of the Assignment (Week 2) and its submission (Week 4), there would be limited time available to seek outside assistance. Secondly, the researcher requested that tutors in the unit Communication Interface 1 did not assist subjects in the completion of the Assignment. Thirdly, subjects were instructed that they should complete the Assignment on their own. Finally, a question was asked in post-test 1 as to whether or not an electronic database tutorial run by the University of Canberra Library had been completed in Weeks 2-4. Even if such a tutorial had been completed by a subject, the researcher was aware that these tutorials were skills-based, and did not include the type of concept-based instruction that comprised the experimental module.

A final intervening variable in the completion of the Information Retrieval Assignment proved to be frustration experienced by some subjects, due to their inability to access the electronic databases necessary to complete the Assignment for three days at the end of Week 3. This frustration was caused by unscheduled computer server "downtime", and is one of the limitations of the study discussed in sub-section 6.2.6 below.

With regard to intervening variables that may impact on the conduct of the experiment generally, the researcher notes that these variables: elapsed time, subject maturation, and the "Hawthorne effect" in which subjects who are given attention from a researcher tend to perform better than those who do
not, were addressed in the following ways. Firstly, the timetable for the
conduct of the experiment was kept to four weeks. This meant that
considerations of elapsed time and subject maturation were unlikely to be
major factors influencing results.

With regard to the Hawthorne effect, two measures were taken: firstly, in the
introduction to the research during the Lecture in Week 1, the researcher
stressed the value of all subjects' participation and input. The researcher was
of the view that the goodwill of the subjects was important to successful
completion of the experiment, as it necessitated both intellectual and time
investments on behalf of the participants. The fact that subjects were new
first year undergraduates, and therefore likely to be motivated and
enthusiastic, was felt to be an advantage in this regard. Subjects were told
that the research was about gathering data on factors affecting information
retrieval, and trialling different teaching techniques to assist students to
become better at information retrieval. The number or type of teaching
techniques to be used was not discussed, and subjects were not told to which
treatment group (if any) they would be allocated.

Secondly, the researcher administered every aspect of the experiment
personally, including attending the Lecture in Week 1 to introduce subjects
to the research; attending all 18 tutorials in Week 2 to collect Consents,
administer Survey 1, distribute the Information Retrieval Assignment, and
teach the experimental module to the experimental treatment group; and
attending the Week 4 lecture to administer Survey 2. In this way, all subjects
received considerable attention from the researcher during the course of the
experiment.

As the experiment was conducted early in first semester with a large cohort
of first year undergraduates, it was considered unlikely that much discussion
of the experiment would take place between tutorial groups, as most
students did not yet know each other socially. Further, it was considered
very unlikely that subjects would conspire to influence the outcome of the experiment. In the first place, they had no reason to do so; in the second place, even if a few subjects had wanted to do so, they were not aware of the anticipated outcomes of the research, and therefore could not know how to influence them, and the size of the sample would tend to negate the impact of any such attempts even if they were undertaken.

6.2.4 Timetable for Conduct of the Experiment

The timetable for the conduct of the experiment was considered carefully to take into account the many variables likely to impact on the successful implementation of the project. The timetable and experimental design were discussed with the University of Canberra Statistician to ensure that design elements necessary for a rigorous experimental study were incorporated.

The timetable for the conduct of the experiment appears at Table 6.4 below.

This timetable enabled the entire cohort to be administered the introduction to searching by the Faculty of Communication Liaison Librarian (Appendix 7), and Consent forms to be distributed, in Week 1 of semester. Survey 1 (pre-test) could be administered during Week 2, the Consents collected, and the experimental module administered to the experimental groups. Subjects were then able to complete post-test 2 (Information Retrieval Assignment) by Week 4. This timetable was tight, but by being so, the impact of intervening variables such as maturation, learning in other subjects, and attrition from the subject, could be minimised.
Table 6-4: Timetable for Conduct of Experiment

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TUTOR</th>
<th>STUDENTS</th>
<th>WHEN</th>
<th>DURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Introduction to searching</td>
<td>Faculty Liaison Librarian</td>
<td>All</td>
<td>Lecture, Week 1, Monday, 1.30-3.00, 2B9</td>
<td>30 minutes</td>
</tr>
<tr>
<td>2. Introduction of project to students</td>
<td>Researcher</td>
<td>All</td>
<td>10 minutes</td>
<td></td>
</tr>
<tr>
<td>3. Distribution of Consent</td>
<td>Researcher</td>
<td>All</td>
<td>5 minutes</td>
<td></td>
</tr>
<tr>
<td>Session 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Collection of Consents</td>
<td>Researcher</td>
<td>All</td>
<td>Tutorials, Week 2</td>
<td></td>
</tr>
<tr>
<td>2. Conduct of Survey 1 (pre-test)</td>
<td>Researcher</td>
<td>All</td>
<td>25 minutes</td>
<td></td>
</tr>
<tr>
<td>3. Experimental instruction</td>
<td>Researcher</td>
<td>Exp groups</td>
<td>45 minutes</td>
<td></td>
</tr>
<tr>
<td>4. Students given Information Retrieval Assignment</td>
<td>Researcher</td>
<td>All</td>
<td>5 minutes</td>
<td></td>
</tr>
<tr>
<td>Session 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students complete Information Retrieval Assignment (post-test 2)</td>
<td>None</td>
<td>All</td>
<td>Students' own time, prior to Tutorial, Week 4</td>
<td>Variable</td>
</tr>
<tr>
<td>Session 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conduct of Survey 2 (post-test 1)</td>
<td>Researcher</td>
<td>All</td>
<td>Lecture, Week 4</td>
<td>20 minutes</td>
</tr>
<tr>
<td>Session 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Students hand in Information Retrieval Assignment</td>
<td>All tutors</td>
<td>All</td>
<td>Tutorials, Week 4</td>
<td>5 minutes</td>
</tr>
<tr>
<td>2. Experimental instruction handout</td>
<td>Control group tutors</td>
<td>Control groups</td>
<td>10 minutes</td>
<td></td>
</tr>
</tbody>
</table>
6.2.5 Data Collection

Data was collected by means of three instruments: Survey 1 (pre-test); Survey 2 (post-test 1); and an Information Retrieval Assignment (post-test 2). These instruments are described in section 6.3. Survey 1 was completed in Week 2 tutorials. The Information Retrieval Assignment was distributed in the same tutorial, and completed assignments were submitted in tutorials in Week 4. Survey 2 was completed in the lecture in Week 4.

The length of time allowed for completion of the Information Retrieval Assignment was decided after discussion with the Faculty of Communication Liaison Librarian. The Liaison Librarian is an expert in information retrieval, and was familiar with the requirements of the research. Two weeks was agreed to be sufficient time for all participants to perform their searches in order to complete the Information Retrieval Assignment using the electronic databases available through the Campus-Wide Information Service.

A problem arose however, with the two Friday tutorials - Friday of Week 4 was Good Friday - a public holiday. The researcher decided that to overcome this problem, the searches for those two groups would be due in tutorials in Week 3 (one week earlier than the other groups). The reasons for this decision were:

1. If the Information Retrieval Assignment was not due until Week 5, participants might lose interest, and not complete the assignments thoughtfully.

2. Students did not physically have to go to the library and book computer time in order to be able to conduct the searches; these could be performed using the computers available to students in the University of Canberra Computer Centre. In fact, the searches could be completed at the end of any of the tutorial sessions for Communication
Interface 1, held in the Computer Centre. It was felt that for the 25 students in Friday tutorials, one week was not an unrealistic amount of time to allow for the search to be conducted. On the other hand, there were real risks of loss of motivation (and therefore, performance, and the question of intervening variables arising because of it), if the Information Retrieval Assignment were not due until Week 5.

3. It was early in the semester, so there was little pressure on students to complete assignments for other units.

6.2.6 Limitations

The researcher acknowledges the difficulties inherent in conducting an experiment in a natural setting such as a university library and computer laboratories. Limitations are noted in this chapter, and in Chapter 7, in the context in which they arise, but they may be summarised as follows:

1. Time constraints. There were two areas in which time constraints were a factor. The first area was in relation to the pre-test and post-test surveys. Most tests of problem-solving ability take approximately one hour to complete, but the researcher did not have one hour to administer the surveys. Further, these surveys needed to gauge not only problem-solving ability, but also knowledge of electronic databases.

There were two courses of action available: either to use a much smaller sample, and administer longer pre-tests and post-tests, or to use a large sample, and administer 25 minute pre-tests and post-tests. This latter alternative had the advantage in that subjects were more likely to answer questions thoughtfully and honestly, and remain motivated, to complete the entire survey, and that many respondents would participate. The researcher wanted to use as large a sample as possible, in order to overcome a problem evident in much of the literature.
reviewed for this research - small sample size. The disadvantage was
that it was possible that the variables being measured would not be
accurately measured, due to insufficient questions being asked. This
disadvantage was overcome by ensuring high content validity in the
instruments used.

The second area in which time constraints were an issue was the
amount of time for which the researcher had access to the sample for
the purpose of administering the experimental treatment. The lecturer
in charge of the students in the experiment had given her permission
for the researcher to access all 18 tutorials in Communication Interface 1
in Week 2 of first semester for the purpose of teaching the experimental
Module and administering the pre-test. The tutorials were of one hour
and fifteen minutes' duration. As the pre-test took approximately 20-25
minutes to deliver, and as Consent forms had to be collected and
introductory comments made, this left approximately 30 - 40 minutes to
teach the experimental Module. The researcher took two steps to deal
with this time constraint: firstly, the researcher taught all 18 tutorials. In
doing this, the intervening variable of teaching style differences could
be ruled out. Secondly, the researcher ensured that every aspect of the
experimental teaching Module was linked to the tenets of the learning
theories under investigation.

2. Technology. Between the time the Information Retrieval Assignment was
distributed in tutorials in Week 2, and when the Assignment was due in
Week 4, 254 subjects had to access the University of Canberra’s
Electronic Research Library (“ERL”). The researcher was satisfied that
the two week time frame was feasible, as this group of databases was
able to be accessed not only from the computers in the library itself, but
also from any of the 100 computers in the Building 10 Computer
Centre. Subjects had 24 hour access to the Computer Centre, and
because it was early in first semester, very few, if any, substantial
assignments in any other units were due. Therefore, use of the
Computer Centre, except for scheduled tutorials, was light.

The researcher was aware that there was an element of risk in relying
on a computer network, as it was possible that an unforeseeable
problem could arise. However, although the network server had been
"down" once or twice in the previous year, it had never been
unavailable for more than two or three days. The researcher was of the
view that even if such a problem did occur, most subjects would still be
able to complete the Information Retrieval Assignment. In fact, such a
problem did occur. At the end of Week 3 (Saturday - Monday), the
computer server that controlled ERL access had three days of
unscheduled “downtime” caused by problems within the network.

Comments from subjects suggested that this “downtime” was a factor
in causing frustration to those who were attempting to complete the
Information Retrieval Assignment over that weekend. It may also have
affected the number of Assignments handed in. Of the 254 subjects, 199
submitted Assignments in Week 4. Despite the technological
difficulties, this still represented a very satisfactory response rate of
78%.

Another limitation related to the use of technology was the information
available online about the content of databases. At the time the
experiment was conducted, the Electronic Research Library home page
contained only a list of computer databases, many of which were
labelled only by acronyms. In the University of Canberra Library, a
hard-copy key to those acronyms was available. This list was not
available in the Computer Centre. It is not known how many subjects
accessed the key to database acronyms. This factor may have affected
the number of databases searched by some subjects.
3. Limited questions on cognitive maturity. As discussed earlier, in the interest of keeping within available time limits, and in order to maintain participant motivation, administration time for the pre-test and post-test had to be kept to approximately 20-25 minutes each. Most of this administration time was taken up by questions central to the main hypotheses to be tested (Table 6-1, hypotheses 1-3). There was however, another correlate that the researcher believed was of value in assisting an understanding of end-user information seeking and retrieving; the construct of cognitive maturity.

Four questions, based on Perry's construct (1968, 1981 in King & Kitchener, 1994; McNeer, 1991 and Mellon & Sass, 1981) of cognitive developmental levels in young adults, were included in the pre-test. Whilst insufficient to allow any firm conclusions to be drawn, the purpose of including these questions was to gather data on possible differences in cognitive maturity in young adults, and to note any relationship with other variables, such as problem-solving ability.

In this section, research design, population and sample, variables, timetable, data collection and limitations have been discussed. In the next section, instruments used to gather data and to measure variables are described.

6.3 Instruments

The research design adopted for the study was a pre-test/post-test control group experiment. Introductory training in electronic database information retrieval was given to all subjects, during the first lecture of Semester 1 for the unit Communication Interface 1.

Using a pre-test (Survey 1), baseline information was gathered on intervening variables, levels of knowledge of electronic database searching, problem solving, and to a limited extent, cognitive maturity.
Two post-tests were designed (Survey 2, and the Information Retrieval Assignment) to ensure that variables pertaining to participant performance outcomes suggested by the hypotheses were measured as accurately as possible. Survey 2 tested the acquisition and recall of basic electronic database facts. The Information Retrieval Assignment was designed to test whether adequate conceptual knowledge had been acquired. As the researcher argues that the teaching of conceptual knowledge is central to bibliographic instruction today, this component was essential. As Bober, Poulin & Vileno (1995, in Martin, ed., 1995:59) remarked, "very few evaluations have attempted to measure student learning at the conceptual level. One possible explanation is that these 'higher-order cognitive skills of analysis, synthesis and evaluation' are more difficult to evaluate".

Participants in pre-formed tutorial groups were allocated randomly to experimental or control treatments, to enable comparison of performance between participants who were given the experimental Module designed to increase information retrieval effectiveness (experimental group), and those who did not (the control group).

6.3.1 Survey 1

In order to meet the requirements for a pre-test/post-test research design, baseline data has to be gathered to enable data generated in the course of the experiment to be put in context and measured accurately. Without this baseline data, any differences between experimental and control group performance would be much harder to establish and to quantify. Survey 1 was designed to gather data on a range of matters pertaining to the establishment of baseline data. Participants were asked to write a "nickname" known only to themselves at the top of the Survey. Subjects were asked to use this same nickname on Survey 2, and on the Information Retrieval Assignment. In this way, comparison of pre-and post-test data for participants was made possible, whilst protecting the anonymity of all participants.
The number of questions in the Survey was determined by balancing the need to gather data sufficient to test hypotheses on the one hand, and practical considerations on the other. The first consideration was time constraints. If intervening variables such as elapsed time and maturation were to be controlled, Survey 1 had to be administered to 18 tutorials in one week. These tutorials were of 90 minutes' duration, and other tasks unrelated the research also had to be completed by students in these classes. Participant motivation was a second important factor. In order to increase the probability that all sections of the Survey would be completed thoughtfully, only questions essential to hypotheses testing were included in Survey 1. The Survey as originally drafted was trialled on two colleagues; time taken to complete it was 45 minutes. As this was too long both in terms of time available, and in maintaining participant motivation to complete, the Survey was simplified, to enable it to be completed by most students within 20-25 minutes.

Section 1 of Survey 1 consisted of nine questions requiring boxes to be ticked and/or a word to be supplied. The questions were designed to gather background information about the participants. This information was essential in that it provided data on intervening variables anticipated to have a bearing on the research results. By gathering this information, correlates relating to performance on the two post-tests (Survey 2, and Information Retrieval Assignment) could be analysed and trends and significant relationships established. Further, the data enabled comparison of features of the experimental and control groups, to ensure that for the purposes of the experimental design, they were comparable.

Question 1.1 of Survey 1 asked subjects to identify their status, in terms of the number of units being studied: full-time or part-time. This variable provided information that helped to generate a profile of the "typical" study participant.
Question 1.2 required the participant to identify his or her faculty of study. This question was included because research has suggested that student performance on information retrieval tasks will be influenced by discipline of study (Borgman, 1989). Whilst it is acknowledged that "faculty and "discipline" are not synonymous, it was felt that there was sufficient variety in the disciplines represented in the current study, for example, Arts, Humanities and Science, using Faculties as the defining parameter, to enable comparisons to be made with the findings of Borgman (1989).

Question 1.3 asked subjects to state their academic major. It was included to categorise more precisely students' differences in terms of academic discipline. However, it was found that this question had to be excluded from the data analysis as many subjects were unable to answer it. The researcher believes that this difficulty arose because the Survey was completed in the second week of what was, for most of the participants, their first year of study. The term "academic major" seemed to be confusing to them. For example, some students interpreted the term to mean "name of degree being studied" (which was the interpretation desired by the researcher); other students supplied the name of their six-unit elective major. The elective major at the University of Canberra is a sequence of six units, or subjects, that a student chooses to study as part of their degree. For example, a student enrolled in the Bachelor of Information Management - Office Management degree will study a combination of 14 compulsory units in communication and information management, and a six unit elective major of their own choosing, from such disciplines as psychology, law, marketing or sports administration. As responses to this question were unreliable, the variable was omitted from the analysis.

Question 1.4 required participants to indicate their age as falling into one of the six stipulated categories (under 20; 20-22; 23-30; 31-40; 41-50; 51 or above). Students aged 30 years and under were divided into three categories,
as historical student demographics for the University of Canberra suggested that most students would be either school leavers (under 20), or young "mature" students. The researcher wished to be able to separate these students in data analysis to be able to determine any correlates between age, and performance on the post-tests.

Question 1.5 (gender) was included to enable any relationship between gender and information retrieval performance and/or problem solving ability to be identified.

Question 1.6 asked participants to indicate their highest existing academic qualification. This information allowed analysis of questions pertaining to correlations between academic qualifications and information retrieval effectiveness and/or problem solving. In order to be able to determine whether students from culturally diverse backgrounds may have performed differently on information retrieval tasks, separate categories were included in this question to enable students to indicate whether they had studied outside Australia ("Year 12 equivalent overseas"; or "Higher degree - please specify degree title and university attended").

Question 1.7 gathered data on participants' prior knowledge of bibliographic instruction and information retrieval.

Question 1.8 established prior knowledge of electronic databases; the participants were asked to indicate if they had ever accessed an electronic database, and if so, how often.

Question 1.9 was divided into three sections about participants' access to, expertise with, and enjoyment of, computers. The researcher included this question because firstly, in the case of computer access, it was possible that students with greater access might more quickly assimilate electronic database skills; secondly, in the case of self-rated computer ability and
computer enjoyment, research had indicated that these factors may influence performance on computer-related tasks (LaLomia & Sidowski, 1993).

Section 2 of Survey 1 comprised 17 straightforward multiple choice questions designed to establish participants' understanding of terminology used in electronic database retrieval. These questions were pertinent to establishing baseline information for the testing of hypothesis 1a: before the experimental treatment, there is no difference between experimental and control groups on electronic database knowledge.

Questions 2.1 - 2.15 were taken from a test bank compiled by Reddy (1988), that was designed to measure knowledge of bibliographic instruction in the areas of database characteristics, search strategy design, concept identification, and the use of truncation, Boolean operators and synonyms in strategy formulation. These variables were used in the data analysis as indicators of knowledge of search terminology and strategy. Questions 2.16 and 2.17 were written by the researcher in order to address questions of interest: firstly, do students believe that databases contain all information on any given topic; and secondly, do students recognise the need to evaluate the relevance of information obtained from a database? The first question relates to whether or not subjects have formed a sufficiently accurate “mental model” of database characteristics. If they believe that one database will be sufficient to provide information for their search, then they have not yet developed an effective mental model of the characteristics of electronic databases.

With regard to the second question, literature suggests (Arnold & Jayne, 1998; Bruce, 1992) that a common misconception about electronic databases is that all the information they contain is credible. As this is not the case, it is important to ascertain whether such a misconception exists, and how widespread it may be.
The validity (accuracy of measurement) and reliability (consistency of measurement) of Section 2 were determined. In order to ensure that content validity was high, each question was selected to test a specific aspect of relevant database knowledge.

Pearson's correlation coefficient between the scores on Survey 1, Section 2 and Survey 2, Section 2 was computed to determine predictive validity of the questions on electronic database knowledge. The correlation coefficient was .4302; p=.000. This is an acceptable coefficient as the "typical" validity coefficient is approximately 0.45 (Sproull, 1995:76).

Statistical reliability for Section 2 was calculated using the Kuder-Richardson KR-20 reliability formula. The KR-20 formula is used when there are only two possible responses to each item (Sproull, 1995:87-88); viz, a correct or an incorrect answer. The reliability coefficient was calculated as .532. This value is rather lower than the "typical" reliability coefficient of 0.7 for a researcher-designed instrument (Sproull, 1995:76). Although this value means that results need to be interpreted with caution, the researcher notes that the more important validity coefficient is acceptable for this section of the Survey. In other words, Section 2 is accurate in that the degree to which it measures what is supposed to be measured - knowledge of electronic databases - is satisfactory (predictive validity coefficient of 0.4302; p = .000), but its reliability (consistency of measurement) is somewhat lower than would normally be desirable. However, as Sproull (1995:76) observes, "of validity and reliability, validity is far more important than reliability ... if an instrument does not measure accurately what it is supposed to measure, there is no reason to use it, even if it does measure consistently."

Section 3 of Survey 1 gathered data on problem-solving and reasoning skills. This data was required in order to establish baseline information for the testing of hypothesis 3: there is a difference in search performance depending on
problem-solving ability; and hypothesis 4: there is a relationship between problem-solving ability and cognitive maturity.

Selection of material for Section 3 was far more complex than the selection of material for Section 2. Whereas questions in Section 2 primarily required participants to recall information - a relatively simple cognitive task (Beyer, 1987) - questions in Section 3 needed to be designed to obtain information on participants' problem-solving and reasoning abilities - higher level cognitive operations on which the literature varies as to definition, nature and measurement. These considerations were compounded by the fact that the entire Survey 1 had to be completed by most participants within 25 minutes; most tests of problem-solving ability alone take an hour or more to administer. The researcher notes that this time constraint was one of the limitations on the study.

With regard to the nature of thinking, Beyer (1987) for example, describes thinking in terms of micro-thinking skills (such as recall); critical thinking skills (e.g., detection of bias) and thinking strategies (problem solving, decision making and conceptualising). Bloom (1976) on the other hand, has formulated a taxonomy of thinking skills of which recall (knowledge) is the lowest order, and evaluation the highest. Thinking, problem solving and reasoning have been identified as the three general cognitive abilities by Nowakowski, Bunda, Working, Bernacki & Harrington (1984). Whilst they disagree on taxonomy, researchers do agree on the higher-order nature of the operations of problem solving and reasoning. The nine questions in Section 3 were included to test elements relating to four significant aspects of thinking: critical thinking; problem solving; deductive and inductive reasoning; and logic.

In order to ensure that the content validity of Section 3 was high, each question was included to test an aspect of one of the thinking skills listed above. Each of the thinking skills represented is germane to information
retrieval performance - especially analysis of the search question, and search strategy formulation, which are types of problem solving. Each of the other cognitive skills included in Section 3 were skills which have been identified in the literature, for example Beyer (1987), as being essential to problem-solving success. Questions 4, 8 and 9 were taken from Bransky, Hadass & Lubezky (1992). Question 5 was adapted from Biehler & Snowman (1993). Question 7 was adapted from a well-known analogy written by Duncker (1945, in Gick & Holyoak, 1980; Anderson, 1985). Table 6-5 lists the question topics comprising Section 3.

Table 6-5: Thinking Skills Tested in Survey 1, Section 3

<table>
<thead>
<tr>
<th>Question No.</th>
<th>Thinking Skill</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Critical thinking: drawing an inference from information presented</td>
</tr>
<tr>
<td>2</td>
<td>Critical thinking: differentiating between opinion and fact</td>
</tr>
<tr>
<td>3</td>
<td>Problem solving: generating alternative explanations which are plausible for a result</td>
</tr>
<tr>
<td>4</td>
<td>Problem solving: controlling variables</td>
</tr>
<tr>
<td>5</td>
<td>Deductive reasoning: using Venn diagrams to show a syllogism</td>
</tr>
<tr>
<td>6</td>
<td>Inductive reasoning: cause and effect; identification of variables</td>
</tr>
<tr>
<td>7</td>
<td>Inductive reasoning: solving a problem by analogy</td>
</tr>
<tr>
<td>8</td>
<td>Logic: “even more so”</td>
</tr>
<tr>
<td>9</td>
<td>Logic: “impossible to know”</td>
</tr>
</tbody>
</table>

Predictive Validity for Section 3 of Survey 1 was calculated. Pearson’s correlation coefficient between the problem-solving scores on Survey 1, Section 3 and Survey 2, Section 3 was 0.3559; p=.000. Although this value is below the “typical” validity coefficient of approximately .45, “many are in the range of .30 to .40” (Sproull, 1995:76). The predictive validity of the section is therefore within usual limits.

Section 4, Survey 1 was included to collect exploratory data on developmental theory, in particular the developmental levels articulated by Perry (1968, in King & Kitchener, 1994). Section 4 provided data that related to hypothesis 4: there is a relationship between problem-solving ability and
cognitive maturity. The idea that one of the correlates of problem-solving ability, and information retrieval effectiveness, is the “maturity” of the thinking behaviours of the student, has intuitive merit for the researcher. There is little information in the literature however as to the type of question that might be used to infer different levels of cognitive maturity. The one instrument purporting to measure developmental levels in undergraduates (Allen, 1983 in Frisch, 1987) was an essay type instrument that took 60 minutes to administer. Instead of reliable instruments to measure “maturity”, one hears comments about students progressing from “immaturity” in first year, to “maturity” in third year; however, the term is usually employed in the context of personality and attitude of the student, not cognitive maturity. Four questions were designed by the researcher in order to gather data that might provide evidence of levels of cognitive maturity. The questions developed were based on Perry’s (1968, in King & Kitchener, 1994) theory of developmental levels. McNeer (1991) and Oberman (1992) have also discussed the possible efficacy of incorporating an understanding of Perry’s developmental levels into the design of bibliographic instruction.

Question 3.1 was designed to separate students who were, in Perry’s terms, “dualistic” thinkers, from those who were “relativistic”. Perry’s theory would suggest that mature, or “relativistic”, thinkers would select alternative (b) for that question.

Similarly, question 3.2 should be answered according to a student’s emphasis on context as a variable in determining appropriateness of behaviour. “Relativistic” thinkers should choose alternative (e) for this question.

Question 3.3 was also designed to separate “relativistic” thinkers from “dualistic” thinkers. According to Perry, “dualistic” thinkers expect one right answer, and are confused when they are told that there is more than one right answer. This theory has substantial anecdotal support from the researcher’s experience, in which students will often want to know what the
"right" theory or answer is. Accordingly, more mature thinkers were expected to select alternative (b) as their answer.

Question 3.4 was included to further differentiate dualistic and relativistic thinkers. The idea for the question was suggested by a discussion of Perry's theory in McNeer (1991). McNeer suggested that a librarian's referral of a student to multiple sources might reinforce a "dualistic" thinker's belief that the librarian does not know the right answer, or that there is nothing specific on their topic in the library. Responses to this question by subjects however suggested that the answer alternatives did not allow differentiation between subjects on the basis of differences in cognitive maturity. Data from this question were therefore excluded from the statistical analysis. Further, due to the time constraints on the administering of Survey 1, it was not expected that all subjects would complete Section 4. The researcher notes that a limitation on the data relating to this Section was the small number of questions used. However, Section 4 was exploratory in nature; Sections 1-3 provided the data necessary to test the hypotheses stemming from the three research questions central to this research: Will type of instruction influence acquisition of knowledge of electronic database searching? Will type of instruction influence information retrieval effectiveness? Are problem-solving ability and information retrieval effectiveness related?

In the next two sub-sections, the post-test instruments will be described.

6.3.2 Survey 2

Survey 2 was administered to all participants who were present at the lecture for the unit Communication Interface 1 in Week 4 of first semester, 1997. Survey 2 (post-test 1) was designed to gather data to enable testing of hypothesis 1b: after the experimental treatment, there is a difference between experimental and control groups on electronic database knowledge.
To enable meaningful comparisons to be made between results from the pre-test (Survey 1) and post-test 1 (Survey 2), the same format was used for Survey 2 as for Survey 1, although Survey 2 was shorter, and took less time to complete. Participants were asked to use the same “nickname” on their second survey as they had used on their first.

Section 1 of Survey 2 gathered background information which might have changed since completion of Survey 1 in Week 2 of Semester 1. There were only two questions in this section; the first related to any bibliographic instruction the student may have undertaken since completing the pre-test, and the second related to whether or not the Information Retrieval Assignment (post-test 2) had been started yet. This question was included as the researcher believed that knowledge of the functioning of electronic databases could improve during the course of completion of the Information Retrieval Assignment.

Section 2 of Survey 2 comprised 12 multiple choice questions designed to measure participants’ understanding of terminology used in electronic database retrieval. If experimental and control group scores on these questions were statistically different from their scores on the same section of the pre-test, then research question 1: will type of instruction influence acquisition of knowledge of electronic database searching, would be answered.

Questions in Section 2, Survey 2 were either the same questions as those appearing in Section 2, Survey 1, or substantially similar. Two new questions were: question 2.1, which tested whether a workable concept of a database had been acquired; and question 2.11, which tested whether participants were aware of one method of evaluating information relevance.

Section 3 of Survey 2 consisted of five questions written by Ennis & Millman (1989) to measure an aspect of critical thinking - hypothesis formulation and testing. Manipulation of hypotheses is one indicator of Perry’s (1968, in King
& Kitchener, 1994) level of “full relativism”. In including these questions, the researcher intended to gather further data on the cognitive maturity of subjects. It was expected that there would be a correlation between scores on the problem-solving questions in Survey 1, Section 3, and the questions on Survey 2, Section 3.

6.3.3 Information Retrieval Assignment

The final data collection instrument in the experiment was an Information Retrieval Assignment. This assignment allowed data to be gathered in order to test hypothesis 2: there is a difference between experimental and control groups on search performance; hypothesis 3: there is a difference in search performance depending on problem-solving ability; and hypothesis 5: good searchers identify more concepts, use a greater number of relevant databases, and construct more effective search strategies, than do poor searchers.

Although comparison of data gathered from Survey 1 and Survey 2 enabled tentative conclusions to be drawn about the acquisition of knowledge of electronic database concepts and terminology, no conclusions about any improvement in search behaviour was possible unless some sort of assessment of these skills was made. Accordingly, the researcher designed the Information Retrieval Assignment to assess a number of factors which should vary depending on search ability.

The Information Retrieval Assignment was distributed to participants at the end of each tutorial in Week 2. Participants were asked to include their “nickname” on the Assignments when they submitted them, to enable comparison of pre-test and post-test 1 scores. Participants were asked to complete the Assignment by performing searches of the University of Canberra Electronic Research Library (ERL). Any database, or combination of databases, available through the ERL was able to be used. Participants were able to try as many different search strategies as they wished.
Participants were directed not to use any of the other databases available, for example, Yahoo, as this was a Web-based search engine and the researcher believed that the databases available needed to be limited in order to control that variable. All information necessary to complete the Assignment was available through the ERL. Further, the ERL databases were able to be accessed from not only the University of Canberra Library, but also the computer laboratories in another building, to which students had 24 hour access, and in which their Communication Interface tutorials were conducted. They were therefore able to complete the Assignment from many different computer terminals, thus (it was hoped) demand on the relatively small number of Library computers would be reduced. This was important, as there were 254 participants involved in the study. Subjects were given two weeks to complete the Assignment.

The relatively tight time frame was dictated by the need to control intervening variables in the study, such as maturation, and knowledge gained about electronic database searching other than that provided during the research. These variables are discussed in section 6.2.2 of this chapter.

In order to encourage participants to complete the Assignment, it was incorporated into the Unit Outline for Communication Interface 1, and was allocated a "Complete/Not Complete" status for assessment purposes. For ethical reasons, a grade was not appropriate for the Assignment - it was intended that an outcome of the research would be a significant difference in search performance between the experimental and the control groups, and/or a difference in performance between participants, depending on their problem-solving ability as measured in Survey 1, Section 3.

The research aim of the Assignment was to enable the measurement of search behaviours and outcomes, but for the participants it had a real benefit in that it enabled the achievement of one of the unit's learning objectives: to familiarise students with computer-based search tools.
The Assignment consisted of three search questions, and participants were asked to search for highly relevant journal articles from specified years on each of these three topics. In order to demonstrate that the searches had been undertaken, the participants were asked to hand in computer printouts of the journal abstracts they had located (not the whole article), and a printout of the search history. The search history is a record of the strategies the participant used to access the information required. These strategies, more than the abstracts themselves, revealed the problem-solving strategies used by the participants. In addition to the abstracts and the search histories, participants were asked to complete a brief (one page) sheet which enabled them to indicate the search terms used (if no search history was handed in), databases searched, and a self-evaluation of their search success for each topic. The self-evaluation questions were included as the literature has indicated that there is quite often a discrepancy between perceived and actual search success with novice searchers. This is known as the phenomenon of the "false positive" (Applegate, 1993); novice searchers often express satisfaction with poor searches.

Three search topics were included, because it was felt that conclusions based on the search of one topic could only be tentative. Too many variables might influence the results, rendering them inconclusive; for example, difficulty interpreting the question; different perceptions of the question; database inaccessibility, or computer downtime.

Each search topic was written at a different level of difficulty. This enabled differences in search patterns that might be contingent on search difficulty to emerge. Further, it was felt that if the searches were too easy, there would be little difference between good searchers and poor searchers in terms of outcomes - all would be likely to be successful. The first search was relatively straightforward in terms of concept identification, but quite difficult in terms of availability of precise information on the databases available, and the year
stipulated. The second question was straightforward both in terms of ease of concept identification, and access to current information on the databases; relatively few databases were required to be searched in order to find appropriate information. The third question required the participant to combine two concepts in an abstract way, and to search a number of databases, in order to gain relevant articles. This was the most complex search task in terms of concept identification.

The manner in which search success is measured is important. There are a number of means suggested in the literature to assess search outcomes; issues in measurement are discussed in section 6.4 of this chapter.

In the following sub-section, details of the experimental Module are described.

6.3.4 The Module

Whereas Survey 1, Survey 2 and the Information Retrieval Assignment were designed to enable capture, measurement and interpretation of the variables related to this study, the teaching module (the "Module") was designed as the experimental treatment that would influence both search knowledge, and search behaviour; it was the vehicle through which these variables would be manipulated, to enable hypotheses to be tested.

The aims of the Module were to improve participants' understanding of electronic databases, and to improve participants' ability to locate appropriate literature on the databases for the completion of university assignments. In other words, both search knowledge and search behaviour were addressed.

In Chapter 3 of this thesis, the literature relating to information retrieval instruction was discussed. In Chapter 4, the utility of cognitive psychology in enabling an understanding of the information retrieval process was discussed. In Chapter 5, three theories of learning, and the strategies they suggest for the teaching of concepts and problem solving, were discussed.
Relevant aspects of these theories were applied to the design of the Module, and are outlined below.

Prior to the administration of the Module to the experimental groups (nine tutorials) in Week 2 of semester, all participants received initial ERL searching instruction on introductory concepts and procedures. A large group presentation was given by the University of Canberra Faculty of Communication Liaison Librarian at the first lecture for the unit in which the experiment was run, Communication Interface 1. This presentation was given in order to ensure that all participants had received instruction in basic search procedures. The half-hour presentation included an on-line demonstration of simple search exercises. Students were able to observe the demonstration as it was projected onto the lecture theatre screen via a computer linkup to the ERL, which was the group of databases that the students would be using to complete their Information Retrieval Assignments. A copy of the slides used by the Faculty Liaison Librarian are attached at Appendix 7. This stage of the experiment is underpinned by Cognitive Flexibility Theory, which suggests the importance of introductory knowledge acquisition (Jacobson & Jacobson, 1993).

The presentation was designed to focus on practical procedures only, as concept-based teaching of electronic database material was the independent variable to be introduced in the Module given to the experimental groups in Week 2 (ie, the week following the introductory presentation).

A number of studies were reviewed in order to determine the best Module content, including: Iiovonen (1995); Humeston (1994); and Hepworth (1991). The theoretical underpinnings of the Module, and some of its elements, were suggested by research reported in Jacobson & Jacobson (1993), discussed in detail in Chapters 4 and 5. The Module itself, the Powerpoint presentation, and the support materials, are the original work of the researcher.
The Module components and their theoretical underpinnings are outlined below. The slides used in the Module may be found at Appendix 6. The search worksheet is included at Appendix 8. The handout prepared for distribution to the control group after both post-tests had been completed is attached at Appendix 9.

Experimental Module: Information Retrieval - Concept Formation
This Module was delivered in Week 2 to experimental treatment groups, in computer laboratories where all students had their own computer through which the ERL databases could be accessed. 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.

These teaching strategies, and the learning theories from which they arise, are summarised as:

<table>
<thead>
<tr>
<th>Learning Theory</th>
<th>Teaching Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bibliographic instruction</td>
<td>concept-based teaching</td>
</tr>
<tr>
<td>Cognitive flexibility theory</td>
<td>use of analogy</td>
</tr>
<tr>
<td>Situated cognition</td>
<td>modelling</td>
</tr>
</tbody>
</table>

Graphics of telephone lines linked to computers (or CD-ROMs, if offline databases) were used to correct existing mental models often held by novice end-users that "there's nothing in the computer". This type of verbal report is a diagnostic technique used in cognitive psychology (Gagne, Yekovich & Yekovich, 1993); students at this point are often not aware that they are searching databases of bibliographic records.
These teaching strategies, and the learning theories from which they arise, are summarised as:

<table>
<thead>
<tr>
<th>Learning Theory</th>
<th>Teaching Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive flexibility theory</td>
<td>introductory stage learning; multiple knowledge representations</td>
</tr>
<tr>
<td>Transforming mental models</td>
<td>experts and multiple mental models; minimising learners' errors; learning as transformation of mental models (similar to Piaget's construct of &quot;cognitive dissonance&quot;)</td>
</tr>
</tbody>
</table>

The "information universe" was represented as a marketplace, in which information has a cost, and there is a lack of uniformity in products. For example, CD-ROM databases of refereed journals are appropriate for academic research and completion of assignments; Internet sources are not so reliable, but may be useful - judgement is required; books and print sources are also important.

These teaching strategies, and the learning theories from which they arise, are summarised as:

<table>
<thead>
<tr>
<th>Learning Theory</th>
<th>Teaching Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive flexibility theory</td>
<td>introductory stage learning; multiple knowledge representations; linking abstract concepts to case examples</td>
</tr>
<tr>
<td>Transforming mental models</td>
<td>focus on causal explanations; experts and multiple mental models; minimising learners' errors; learning as transformation of mental models</td>
</tr>
</tbody>
</table>

Some of the metacognitive processes characteristic of expert searchers were discussed and modelled; for example, the importance of the quality and characteristics of the information source itself; a precise search is not the only goal; source and quality in terms of student need are equally important.

Differences between scholarly journals and magazines for research purposes were discussed.
These teaching strategies, and the learning theories from which they arise, are summarised as:

<table>
<thead>
<tr>
<th>Learning Theory</th>
<th>Teaching Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bibliographic instruction</td>
<td>concept-based teaching; novice-expert differences; rules vs heuristics</td>
</tr>
<tr>
<td>Cognitive flexibility theory</td>
<td>linking abstract concepts to case examples</td>
</tr>
<tr>
<td>Situated cognition</td>
<td>knowledge-rich &quot;authentic&quot; situations; modelling; articulation, reflection, confronting misconceptions</td>
</tr>
<tr>
<td>Transforming mental models</td>
<td>experts and multiple mental models</td>
</tr>
</tbody>
</table>

Information retrieval from computer databases was compared to information storage and retrieval mechanisms used by the human brain, in order to address a possible misconception that the computer has the ability to make qualitative judgments.

These teaching strategies, and the learning theories from which they arise, are summarised as:

<table>
<thead>
<tr>
<th>Learning Theory</th>
<th>Teaching Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive flexibility theory</td>
<td>multiple knowledge representations; introduction of complexity</td>
</tr>
<tr>
<td>Transforming mental models</td>
<td>experts and multiple mental models</td>
</tr>
</tbody>
</table>

Following the tutor's presentation on concept formation, the second stage 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.
These teaching strategies, and the learning theories from which they arise, are summarised as:

<table>
<thead>
<tr>
<th>Learning Theory</th>
<th>Teaching Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive flexibility theory</td>
<td>multiple knowledge representations; introduction of complexity; linking abstract knowledge to case examples</td>
</tr>
<tr>
<td>Transforming mental models</td>
<td>experts and multiple mental models; structured knowledge for problem solving; learning as transformation of mental models</td>
</tr>
</tbody>
</table>

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. Examples of inappropriate search strategies were shown; and inappropriate truncation. Inappropriate search terms such as "impact of" and "effect on" were discussed. The point was made that expert searchers can spend more time preparing a search than actually executing it.

These teaching strategies, and the learning theories from which they arise, are summarised as:
In the remaining tutorial time, subjects practiced formulating and executing searches on subjects relevant to the unit they were studying, themselves.

These teaching strategies, and the learning theories from which they arise, are summarised as:

<table>
<thead>
<tr>
<th>Learning Theory</th>
<th>Teaching Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bibliographic instruction</td>
<td>concept-based teaching; novice-expert differences; rules vs heuristics</td>
</tr>
<tr>
<td>Cognitive developmental theory</td>
<td>speculation on outcomes; experiential learning – “hands on”</td>
</tr>
<tr>
<td>Cognitive flexibility theory</td>
<td>concept inter-relationships; advanced stage learning; multiple knowledge representations; introduction of complexity; linking abstract knowledge to case examples</td>
</tr>
<tr>
<td>Situated cognition</td>
<td>modeling</td>
</tr>
<tr>
<td>Transforming mental models</td>
<td>experts and multiple mental models</td>
</tr>
</tbody>
</table>

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

These teaching strategies, and the learning theories from which they arise, are summarised as:
At the end of each Week 2 tutorial, the Information Retrieval Assignment was distributed to all subjects. Data gathered through that assignment provided information on numerous variables thought to be involved in the measurement of search performance. One key measure used to quantify search success has often been relevance of retrieved items. In the following section, issues relating to measurement of search performance are discussed.

### 6.4 Measurement: Relevance

In information retrieval, the traditional measure of relevance of retrieved items has been a combination of two factors: precision; and recall. These factors are calculated as:

\[
\text{precision} = \frac{\text{number of relevant documents retrieved}}{\text{number of retrieved documents}}
\]

\[
\text{recall} = \frac{\text{number of relevant documents retrieved}}{\text{number of relevant documents}}
\]

The second measure - recall - has, however, been questioned by a number of researchers. Bellardo (1985) for example, distinguished between the efficacy of precision and recall as predictors of search effectiveness. Whereas her findings suggested that precision did not vary a great deal between searchers with different attributes, recall did. This finding has also been reported by other researchers; for example, Penhale & Taylor (1986). Fenichel (1981, in Bellardo, 1985) found that novice searchers obtained an overall precision mean of 80%; experienced searchers precision of about 81%. However, for recall, novices produced a mean of 24%, while the experienced searchers...
achieved a mean recall of 46%. In Bellardo's study, 45 searches produced precision ratios of 100%; however those 45 searches achieved recall of between 2 and 70%.

Harter (1996) discussed in detail the topic of relevance judgments, and the lack of uniformity in the criteria which end-users employ to reach a relevance judgment - for example, formal education, subject knowledge, motivation and so on. Harter made the point that because of these differences, the idea that relevance judgments can be used to measure retrieval performance is not sound. He concluded that:

```
variations in relevance assessments can usefully be seen as a special case of the more general problem of individual differences in information retrieval. Perhaps the single most compelling conclusion that can be reached from decades of research in information retrieval is the importance of individual differences among cases (or to put it another way, the lack of overlap) (Harter, 1996:48).
```

Robertson & Hancock-Beaulieu (1992) also concluded that relevance measurement is a qualitative issue, not a quantitative one.

Another tool used to quantify search behaviour is the transaction log - a computer record of all end-user interactions with a computer terminal. A transaction log records, for example, search strategies used, and the time they were performed. Wallace (1993) observed that transaction logs are useful, as they are unobtrusive; users' perceptions about what they do as recorded in, for example, questionnaires, often do not match what they actually have done. Surveys measure attitudes, while transaction logs record specific forms of behaviour - motor skills, basic knowledge, and conceptual knowledge. The researcher is of the view that this information is very useful. For this reason, subjects in the current study were required to print search histories of their searches; a form of transaction log.
A Ratings Sheet (Appendix 10) was designed by the researcher to enable the Information Retrieval Assignment data to be coded and analysed. A number of design elements were taken into account when determining which evaluation criteria should be used. Kirk (1975, in Young & Ackerson, 1995) described three areas of measurement appropriate to bibliographic instruction programs that are applicable to the present study: firstly, the content of the instruction (i.e., whether the Module content was learned). This element was measured by Survey 2 (post-test 1). The second unit of measurement suggested by Kirk was the actual process of the search (the steps students go through to find information; in the present study, this was measured by using the criteria discussed below. The third unit of measurement suggested by Kirk is the product of the search (in this case, abstracts obtained by students), as measured by the quality of the references obtained. Such bibliography ratings have been used in several studies, for example: Kohl & Wilson (1986); Zahner (1992); and Young & Ackerson (1995).

Although Young & Ackerson (1995) provided a format for a Bibliography Rating Sheet, in the researcher's view this sheet was too narrow in its criteria formulation to achieve the level of detail desired in the present study; instead, a range of criteria suggested by various authors arising from the literature review (see Chapter 3) was developed.

Data were classified into two main groups: Search Strategy, and Retrieved Items. Table 6-6 shows the rating criteria under each of these headings.
Table 6-6: Rating Criteria for Information Retrieval Assignment

<table>
<thead>
<tr>
<th>A. SEARCH STRATEGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of concepts</td>
</tr>
<tr>
<td>Number of inappropriate concepts</td>
</tr>
<tr>
<td>Number of relevant databases</td>
</tr>
<tr>
<td>Number of irrelevant databases</td>
</tr>
<tr>
<td>Number of databases (total)</td>
</tr>
<tr>
<td>Number of synonyms</td>
</tr>
<tr>
<td>Number of reformulations</td>
</tr>
<tr>
<td>Use of truncation: correct, incorrect, mixed or not used</td>
</tr>
<tr>
<td>Use of Boolean operators: and; or; not; or; and, or, not; and, not</td>
</tr>
<tr>
<td>Suitable search strategies: yes/no</td>
</tr>
<tr>
<td>Self-evaluation of search success</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. RETRIEVED ITEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source (rating: inadequate, marginally adequate, adequate, good, superior)</td>
</tr>
<tr>
<td>Currency (same rating)</td>
</tr>
<tr>
<td>Relevance (same rating)</td>
</tr>
<tr>
<td>Search success (same rating)</td>
</tr>
</tbody>
</table>

The first group was Search Strategy data; i.e., the thinking processes used by search participants to formulate searches. It was expected that the variables included in the search strategy data would be able to be correlated with firstly, experimental treatment, and secondly, problem solving ability. Variables included in the search strategy group included: Number of Concepts; Number of Inappropriate Concepts; Number of Relevant and Irrelevant Databases accessed; Total Number of Databases accessed; Self-evaluation of Search Success; Number of Synonyms; Use of Truncation; Number of Search Strategy Reformulations; Use of Boolean Operators; and Suitability of Search Strategies. With regard to Strategy Reformulation, Dalrymple & Zweizig (1992) have discussed the significance of a model (Williams, 1984 in Dalrymple & Zweizig, 1992) in which searching is facilitated by attention to contextual cues that enable the searcher to generate new words, change direction, or reformulate the search process. For this
reason, the researcher thought the number (and type) of reformulations would provide useful data.

The second classification of the Information Retrieval Assignment data was Retrieved Items (Table 6-6). Variables were Source (for example, journal or magazine), Currency, Relevance (determined by the assessment of source and currency), and finally, Overall Search Success (determined by an evaluation of relevance of all the items found for the search topic). Source and Currency of article were not coded separately after the first 20 Assignments were processed, as the researcher found that this was not necessary. Rather, Search Success was able to be gauged by evaluating source and currency, then allocating a relevance rating, then counting the number of relevant articles per topic to enable an evaluation of Search Success to be made. The total number of variables generated for each search topic was 15; each one of these variables was coded for each search topic (that is, 45 variables for each Assignment). When participants had not completed all search topics, or had, for example, not submitted their search history, the data that was submitted was coded, and blanks left to indicate information not provided.

For each research topic, every article for which a citation was provided was assessed for relevance to the topic. Relevance was based on currency (ie year of publication); source (ie academic journal or generalist magazine); and relationship to the topic. For each article, a score for relevance was given (0 = “Inadequate”; 1 = “Marginally adequate”; 2 = “Adequate”; 3 = “Good”; 4 = “Superior”). Over the course of coding, the researcher developed a scoring sheet for frequently cited articles and their relevance ratings, to ensure that the same rating was applied to each article. Those assignments coded first were re-checked to ensure consistent coding had been applied.

Search success for each topic was then evaluated by considering how many articles were found, and their relevance to the topic. A rating for the search
success for each topic was then given: 0 = “Inadequate”; 1 = “Marginally adequate”; 2 = “Adequate”; 3 = “Good”; and 4 = “Superior”.

The procedures described above were followed in order to ensure as far as possible that elements comprising the rating were quantitative rather than qualitative. However, evaluating search success necessarily involves judgement, which for the purposes of experimental validity, is not desirable, as the issues of rater bias, expertise and consistency of rating arise. Methods used to neutralise these biases are described below.

(a) In order to eliminate rater bias, participants’ assignments were rated “blind”; that is, it was not known whether the assignment belonged to an experimental subject, or a control subject. As participants submitted assignments using code names to obscure their identity, this meant that most assignments were not able to be identified until they had been compared with a master list of code names and tutorial numbers.

(b) With regard to rater expertise, the researcher holds a Bachelor’s degree in education, and was in 1997 an academic with six years’ experience teaching at university; she has expertise in, and experience with, evaluating students’ assignments.

(c) With regard to consistency of rating, the researcher rated all assignments personally, so inter-rater bias was therefore not an issue. However, the rating of thousands of citations is a large task, and the researcher has noted earlier that methods of rating were quantitative rather than qualitative wherever possible to address the issue of consistency of rating across assignments.

Seven of the eleven variables in the Search Strategy group were determined by counting the occurrence of the variable. For example, for search topic one, if the participant had identified three concepts for that topic, the number 3
was recorded in the database for that participant for that variable for that topic.

Use of truncation was rated as either "correct", "incorrect", "mixed" (both correct and incorrect truncation used) or "not used". Use of Boolean operators was classified as "and", "or", "not", "and/or", "and/or/not", or "and, not". The great majority of participants used only one or two of these possible combinations. For truncation use, even though some judgment was required, it was very straightforward; for Boolean operators, the process involved reading search histories and counting use of the various operator combinations.

The variable "Suitable Strategies" was a judgment, based on whether or not wording in a search strategy was appropriate. For example, in Topic 1, a strategy including the terms "literacy" and "high school" was judged as unsuitable, as the topic stipulated literacy in higher education.

Provision on the Ratings Sheet was also made for subjects' comments. Not all subjects made comments on their Assignment, but those who did usually fell into certain categories. Categories included on the Ratings Sheet included: "enjoyable", "learned something", "frustrating", "many hours", "computers unavailable", "Webspirs down", "more training necessary", and "other".

6.5 Data Analysis

A number of statistical analyses were conducted to test hypotheses. Analyses included a paired sample t-test, correlation, chi-square, and log cross product ratio analysis. Log cross product ratios provide an indication of the chances or odds of one variable affecting the occurrence of another (Saracevic & Kantor, 1988).

In the next chapter, results for Phase 1 are discussed.
7. PHASE 1 - RESULTS

In this chapter, data gathered in Survey 1 (pre-test), Survey 2 (post-test 1) and the Information Retrieval Assignment (post-test 2) are reported. In section 1, descriptive statistics are provided. In section 2, results for central hypotheses are reported. In section 3, correlates not central to the main hypotheses, but nevertheless of interest, are reported. Section 4 provides a summary of results.

7.1 Background Variables

In this section, response rates to the three instruments used; descriptive statistics for Surveys 1 and 2; and characteristics of the sample (background or intervening variables); are discussed.

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; gender; 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.

7.1.1 Participants - Response Rates

Pre-test (Survey 1)

All students attending tutorials in Week 2 of semester 1, 1997 in the unit Communication Interface 1 were invited to participate in the study; all students signed Consent forms and completed Survey 1 (n = 254); a response rate of 100%. 

Chapter 7: Phase 1 - Results
**Post-test 1 (Survey 2)**

The second survey was completed during the Week 4 Communication Interface 1 lecture. All students at the lecture, except for those who arrived late, completed the survey ($n = 147$). Survey 2 was completed by 57.6% of students who had completed Survey 1 in Week 2.

**Post-test 2 (Information Retrieval Assignment)**

Of the 254 assignments distributed to students in the Week 2 tutorial, 199 were submitted for analysis; a response rate of 78%.

### 7.1.2 Descriptive Statistics: Surveys 1 and 2

Validity and reliability measures are discussed in Chapter 5, Section 5.3.1. Summarised below in Table 7.1 are descriptive statistics for Survey 1 (pre-test) - Section 2 (Electronic Database Knowledge); and Section 3 (Problem Solving).

**Table 7-1: Descriptive Statistics for Electronic Database (Survey 1, Section 2) and Problem Solving (Survey 1, Section 3) Knowledge Measures Total Sample ($n = 254$)**

<table>
<thead>
<tr>
<th>Scale</th>
<th>No. of Items</th>
<th>Validity</th>
<th>Reliability</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Database Knowledge</td>
<td>17</td>
<td>.4302</td>
<td>.532</td>
<td>10.71</td>
<td>2.622</td>
<td>4-16 (12)</td>
<td>-.099</td>
<td>-.397</td>
<td>Approximates normal curve</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>9</td>
<td>.3559</td>
<td>.3715</td>
<td>5.713</td>
<td>1.754</td>
<td>0-9 (9)</td>
<td>-.556</td>
<td>.365</td>
<td>Approximates normal curve - short right tail</td>
</tr>
</tbody>
</table>

As can be seen from Figure 7-1 below, scores on Survey 1, Section 2 (Electronic Database Knowledge) approximated the normal curve.
Figure 7-1: Scores on Survey 1, Section 2: Electronic Database Knowledge Questions - Total Sample

Figure 7-2 below indicates that scores on Survey 1, Section 3 (Problem Solving), also approximated the normal curve.
Figure 7-2: Scores on Survey 1, Section 3: Problem Solving Questions - Total Sample

![Bar chart showing scores on Survey 1, Section 3: Problem Solving Questions]

Survey 1 Total Section 3

Summarised below are descriptive statistics for Survey 2, Section 2 (Electronic Database Knowledge) and Section 3 (Problem Solving).

Table 7-2: Descriptive Statistics for Electronic Database (Survey 2, Section 2) and Problem Solving (Survey 2, Section 3) Knowledge Measures

<table>
<thead>
<tr>
<th>Scale</th>
<th>n</th>
<th>No. of Items</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDB</td>
<td>172</td>
<td>12</td>
<td>7.564</td>
<td>1.880</td>
<td>2-12 (10)</td>
<td>-.285</td>
<td>.064</td>
<td>Approximates normal curve</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>164</td>
<td>5</td>
<td>3.073</td>
<td>1.133</td>
<td>0-5 (5)</td>
<td>-.658</td>
<td>.132</td>
<td>Approximates normal curve - short right tail</td>
</tr>
</tbody>
</table>

Figure 7-3 below indicates that scores on Survey 2, Section 2 (Electronic Database Knowledge) approximated the normal curve.
Figure 7-3: Scores on Survey 2, Section 2: Electronic Database Knowledge

Figure 7-4 below indicates that scores on Survey 2, Section 3 (Problem Solving), also approximated the normal curve, with a slightly shortened right tail.

Figure 7-4: Scores on Survey 2, Section 3: Problem Solving Questions
7.1.3 Characteristics of sample

Pre-test (Survey 1 - Section 1: Background Information)

Background variables for the participants are described below. Information on these variables was gathered in Section 1 of Survey 1 (pre-test), administered to subjects at the beginning of tutorials in Week 2. Variables included Gender, Age, Highest Existing Academic Qualification, whether studying Full-time or Part-time, Faculty of Study, Access to Computers, Computer Ability and Computer Enjoyment, Experience using Electronic Databases, and Completion of Library Tours. In italics after the heading for each variable is the question as it appeared on Survey 1. Total numbers of respondents vary as not all subjects answered all questions. Survey 1 is attached at Appendix 3.

Table 7-3: Gender

<table>
<thead>
<tr>
<th>Response category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>167</td>
<td>68.0%</td>
</tr>
<tr>
<td>Male</td>
<td>80</td>
<td>32.0%</td>
</tr>
<tr>
<td>Total</td>
<td>247*</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Of the 254 participants, 247 completed the gender question; 68% of the participants were female.

Table 7-4: Age

<table>
<thead>
<tr>
<th>Response category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>under 20</td>
<td>108</td>
<td>42.5%</td>
</tr>
<tr>
<td>20-22</td>
<td>46</td>
<td>18.1%</td>
</tr>
<tr>
<td>23-30</td>
<td>51</td>
<td>20.1%</td>
</tr>
<tr>
<td>31-40</td>
<td>28</td>
<td>11.0%</td>
</tr>
<tr>
<td>41-50</td>
<td>18</td>
<td>7.1%</td>
</tr>
<tr>
<td>51 or above</td>
<td>3</td>
<td>1.2%</td>
</tr>
<tr>
<td>Total</td>
<td>254</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Chapter 7: Phase 1 - Results
The small range of ages for the second category (20-22 years) was chosen as it was expected that most subjects would be under the age of 22. The researcher wanted to separate school leavers and slightly older subjects, as one of the aims of the research was to investigate any development in cognitive maturity as reflected in problem-solving ability, as a function of age. Breaking down age groups into smaller than usual increments for research purposes therefore seemed appropriate.

Most participants were in fact in the lowest two age categories; 42.5% were aged under 20 years, and 18.1% were aged between 20-22 years. In all, 60.6% of participants were aged 22 years and under.

Table 7-5: Education

*Question: What is your highest existing academic qualification?*

- Year 12 Australia
- Year 12 equivalent overseas in .................(country)
- TAFE qualification (please specify):
- Undergraduate degree (please specify degree title and university attended)
- Higher degree (please specify degree title and university attended)

<table>
<thead>
<tr>
<th>Response category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Year 12 or equivalent</td>
<td>4</td>
<td>1.6%</td>
</tr>
<tr>
<td>Year 12 Australia</td>
<td>176</td>
<td>71.1%</td>
</tr>
<tr>
<td>Year 12 equivalent overseas</td>
<td>12</td>
<td>4.7%</td>
</tr>
<tr>
<td>TAFE</td>
<td>45</td>
<td>17.9%</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>10</td>
<td>4.0%</td>
</tr>
<tr>
<td>Higher degree</td>
<td>4</td>
<td>1.6%</td>
</tr>
<tr>
<td>Total</td>
<td>251</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

The highest academic qualification of the majority of participants was Year 12 in Australia (71.1%). Students who had completed a TAFE qualification comprised the second largest group (17.9%).
Table 7-6: Status

*Question: Are you studying: ☐ Full-time ☐ Part-time*

<table>
<thead>
<tr>
<th>Response category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-time</td>
<td>197</td>
<td>78.2%</td>
</tr>
<tr>
<td>Part-time</td>
<td>55</td>
<td>21.8%</td>
</tr>
<tr>
<td>Total</td>
<td>252</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Most participants (78.2%) were studying a full-time load.

Table 7-7: Faculty of Study

*Question: Faculty of Study: ☐ Applied Science; ☐ Communication; ☐ Education; ☐ Environmental Design; ☐ Information Science; ☐ Management*

<table>
<thead>
<tr>
<th>Response category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied Science</td>
<td>29</td>
<td>11.5%</td>
</tr>
<tr>
<td>Communication</td>
<td>128</td>
<td>50.6%</td>
</tr>
<tr>
<td>Education</td>
<td>39</td>
<td>15.4%</td>
</tr>
<tr>
<td>Information Science</td>
<td>8</td>
<td>3.2%</td>
</tr>
<tr>
<td>Management</td>
<td>49</td>
<td>19.4%</td>
</tr>
<tr>
<td>Environmental Design</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total</td>
<td>253</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

The majority of students were enrolled in the Faculty of Communication (50.6%); followed by Management (19.4%), Education (15.4%), Applied Science (11.5%) and Information Sciences and Engineering (3.2%). The sample was representatives of four of the six faculties; in particular, Communication. Information Sciences & Engineering comprised only 3.2% of the sample, and there were no Environmental Design participants. In terms of discipline of study, Arts, Humanities and, to a lesser extent, Science, were represented.
Table 7-8: Computer Access

Question: About your experience with computers

(a) Have you used a computer: (tick more than one box if appropriate)

☐at home ☐at work ☐at school ☐other (please specify)

<table>
<thead>
<tr>
<th>Response category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>At home</td>
<td>20</td>
<td>8.0%</td>
</tr>
<tr>
<td>At work</td>
<td>15</td>
<td>6.0%</td>
</tr>
<tr>
<td>At school</td>
<td>24</td>
<td>9.6%</td>
</tr>
<tr>
<td>Home, work</td>
<td>42</td>
<td>16.9%</td>
</tr>
<tr>
<td>Home, school</td>
<td>75</td>
<td>30.2%</td>
</tr>
<tr>
<td>Work, school</td>
<td>4</td>
<td>1.6%</td>
</tr>
<tr>
<td>Home, work, school</td>
<td>69</td>
<td>27.7%</td>
</tr>
<tr>
<td>Total</td>
<td>249</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Over 74% of participants had access to computers at home, and in at least one other location (home and school: 30.2%; home and work: 16.9%; home, school and work: 27.7%). No participants reported having absolutely no access to computers.

Table 7-9: Computer Ability

Question: About your experience with computers

(b) In general, would you describe your ability to use a computer as:

☐poor ☐fair ☐good ☐excellent

<table>
<thead>
<tr>
<th>Response category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>43</td>
<td>16.9%</td>
</tr>
<tr>
<td>Fair</td>
<td>117</td>
<td>46.1%</td>
</tr>
<tr>
<td>Good</td>
<td>85</td>
<td>33.5%</td>
</tr>
<tr>
<td>Excellent</td>
<td>9</td>
<td>3.5%</td>
</tr>
<tr>
<td>Total</td>
<td>254</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Participants were asked to rate their computer ability on a scale from "Poor" to "Excellent". Most participants (79.6%) rated their ability as "Fair" (46.1%) or "Good" (33.5%). Few (3.5%) felt their ability was "Excellent", whilst 16.9% felt their ability was "Poor". The researcher notes that actual computer ability if measured objectively may not have corresponded precisely to the
self-rating. A self-rating was regarded as sufficient, however, as it was not expected that computer ability would be a major factor influencing the conduct of the research. Further, computer ability comprises many discrete elements; a person proficient with word processing might be ignorant of spreadsheet applications. What was required of the present study was a general indication of a participant's confidence with using computers.

Table 7-10: Computer Enjoyment

Question: About your experience with computers
(c) Do you enjoy using computers:
☐ very much ☐ quite a lot ☐ not much ☐ I don’t like using computers at all

<table>
<thead>
<tr>
<th>Response category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very much</td>
<td>62</td>
<td>24.6%</td>
</tr>
<tr>
<td>Quite a lot</td>
<td>131</td>
<td>52.0%</td>
</tr>
<tr>
<td>Not much</td>
<td>54</td>
<td>21.4%</td>
</tr>
<tr>
<td>Not at all</td>
<td>5</td>
<td>2.0%</td>
</tr>
<tr>
<td>Total</td>
<td>252</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Most participants (76.6%) enjoyed using computers “Very much” (24.6%) or “Quite a lot” (52%); 23.4% did not enjoy using computers.

Table 7-11: Use of Electronic Databases

Question: About your knowledge of electronic databases:
(a) Have you ever used an electronic database to search for information? ☐ Yes ☐ No
(b) If Yes, would you say that you have used such a database:
☐ occasionally (once or twice) ☐ sometimes (no more than several times a year)
☐ regularly (several times a month)

<table>
<thead>
<tr>
<th>Response category</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>84</td>
<td>33.1%</td>
</tr>
<tr>
<td>If Yes; Occasionally (have used once or twice)</td>
<td>65</td>
<td>25.6%</td>
</tr>
<tr>
<td>Sometimes (no more than several times a year)</td>
<td>61</td>
<td>24.0%</td>
</tr>
<tr>
<td>Regularly (several times a month)</td>
<td>44</td>
<td>17.3%</td>
</tr>
<tr>
<td>Total</td>
<td>254</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
The modal response for this question was "No" (33.1%); 25.6% of participants had used an electronic database "Once or Twice" (25.6%); an almost equal number had used an electronic database "No more than several times a year" (24%). Slightly over 17% used an electronic database "Several times a month".

Table 7-12: Completion of Library Tours

Questions: (a) Have you completed a library tour at Canberra University?
☐ Yes ☐ No. If Yes, please state (i) name and duration of course; (ii) year undertaken.

<table>
<thead>
<tr>
<th>Completion of UC library tour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Category</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

(b) Have you completed a library tour at school, or at any other university?
☐ Yes ☐ No

<table>
<thead>
<tr>
<th>Completion of any library tour at any time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Category</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

(c) Have you studied the unit Research Skills which is offered by the Faculty of Communication at this University? ☐ Yes ☐ No

<table>
<thead>
<tr>
<th>Completion of, or enrolment in, Research Skills unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Category</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
Nearly 72% of participants had not completed any kind of University of Canberra Library tour; 78.2% had not completed a library tour at any other time; and only 2.8% of participants were currently enrolled in, or had completed, the unit Research Skills, which is offered by the University of Canberra as an introduction to research methods for undergraduates using traditional paper-based, and electronic, sources. Most students had not completed any kind of bibliographic or electronic database instruction - which in terms of this factor as a possible intervening variable in the study, was favourable. The 28% of subjects who had completed a University of Canberra library tour, were distributed evenly between experimental and control treatments.

The most usual participant in the study was a full-time female school-leaver, enrolled in the Faculty of Communication, who had access to computers at home and at school, rated her computer ability as fair to good, enjoyed using computers quite a lot but had little knowledge of, or experience with, electronic databases. This “typical” subject was appropriate for the study for a number of reasons. As they were school leavers, the subjects were unlikely to have had much exposure to electronic databases. The fact that they had access to computers, rated their ability as “fair” to “good”, and enjoyed using computers “quite a lot”, meant that intervening variables of prior knowledge of electronic databases, computer anxiety and lack of understanding of computers were not likely to impact significantly on results. Moreover, as 60.6% of the subjects were under the age of 22, observations about cognitive maturity in young adults might be made.
7.2 Hypotheses

The five research questions to be addressed were discussed in Chapter 4. They are:

1. Will type of instruction influence acquisition of knowledge of electronic database searching?
2. Will type of instruction influence information retrieval effectiveness?
3. Are problem-solving ability and information retrieval effectiveness related?
4. Are problem-solving ability and cognitive maturity related?
5. Are there any differences in the search behaviour of more effective and less effective searchers?

In this section, results for the hypotheses relating to research questions 1, 2 and 3 will be analysed in detail. Section 7.3 contains results for research questions 4 and 5, together with an analysis of the impact of intervening variables.

Hypotheses, stated in the null form, arising from the research questions, are listed in Table 7-13 below. In section 7.4, a summary of results is provided.
Table 7-13: Summary of Hypotheses (Null Form) and Instruments

<table>
<thead>
<tr>
<th>No.</th>
<th>Hypotheses (Null Form)</th>
<th>Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>There is no difference between experimental and control groups on electronic database knowledge in the pre-test</td>
<td>Survey 1, section 2: Electronic Database Knowledge (pre-test)</td>
</tr>
<tr>
<td>1b</td>
<td>There is no difference between experimental and control groups on electronic database knowledge in post-test 1</td>
<td>Survey 2, section 2: Electronic Database Knowledge (post-test 1)</td>
</tr>
<tr>
<td>2</td>
<td>There is no difference between experimental and control groups on search performance</td>
<td>Information Retrieval Assignment (post-test 2)</td>
</tr>
<tr>
<td>3</td>
<td>There is no difference in search performance depending on problem-solving ability</td>
<td>Information Retrieval Assignment (post-test 2) and Survey 1, section 3: Problem-solving Ability</td>
</tr>
<tr>
<td>4</td>
<td>There is no relationship between problem-solving ability and cognitive maturity</td>
<td>Survey 1, section 3: Problem-solving Ability and Survey 1, section 4: Cognitive Maturity</td>
</tr>
<tr>
<td>5</td>
<td>Good searchers do not identify more concepts, use a greater number of relevant databases, and construct more effective search strategies, than do poor searchers.</td>
<td>Information Retrieval Assignment</td>
</tr>
</tbody>
</table>

7.2.1 Research Question 1

The first research question was: will type of instruction influence acquisition of knowledge of electronic database searching?

In order to establish that the experimental and control groups were equivalent on existing knowledge of terms associated with electronic database searching, scores on the pre-test (Survey 1, Section 2) were compared.

*Hypothesis 1a (null): There is no difference between experimental and control groups on electronic database knowledge in the pre-test.*
If Hypothesis 1a (null) was able to be accepted, it could be concluded that the experimental and control groups were equivalent in terms of existing knowledge of electronic databases, as measured on the pre-test.

A t-test for equality of means was used to determine differences between groups. A t-test was appropriate as all the assumptions necessary for its application were met, viz: interval scale of measurement; random sampling from the population of interest; and normal distribution of scores (see Figure 7-1).

Results indicated no significant difference between scores for experimental and control groups on knowledge of electronic databases (p = .723).

The decision was made to accept the null hypothesis, and to conclude that experimental and control groups were equal in terms of existing level of knowledge of electronic database searching.

The next question then became whether or not there was a difference between groups on the post-test (Survey 2) measure of electronic database knowledge.

Hypothesis 1b (null): There is no difference between experimental and control groups on electronic database knowledge in post-test 1.

A t-test indicated that the mean for the control group was in fact lower by 4.7% on Survey 2 than on Survey 1. The experimental group mean 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).
The decision was made to reject the null hypothesis, and to conclude that there was a significant difference between experimental and control groups in terms of level of knowledge of electronic database searching on the post-test.

As there was no significant difference between experimental and control groups on electronic database knowledge in the pre-test, and there was a significant difference between those groups on the post-test, and intervening variables were controlled, it can be concluded that the teaching Module was successful in improving participants' knowledge of terms associated with electronic database searching.

7.2.2 Research Question 2

The second research question was: will type of instruction influence information retrieval effectiveness? Information retrieval effectiveness was measured using a range of variables gathered from the Information Retrieval Assignment (post-test 2).

Hypothesis 2 (null): There is no difference between experimental and control groups on search performance.

Data relating to Hypothesis 2 required extensive coding and classification. For ease of reference, this section is divided into three sub-sections: Measurement; Variables Determined by Frequency; and Other Variables.

7.2.2.1 Measurement

When evaluating the success of a search, the question arises as to how success is to be gauged. Several studies have determined search success by rating a number of variables separately: source (eg academic journal or magazine); currency of retrieved item; and relevance of retrieved item; and
then combining these to arrive at a single score for search success on a scale of 0 (inadequate) to 4 (superior). This method requires, and depends on, rater judgment.

In the present study, this rating scale alone was not used to score search success, as relevance judgments have been found to vary according to time and stringency pressures, rating scales used, definition of relevance, and even order of presentation for judgment (Burpin, 1992). In the researcher's view relevance judgments were far too dependent on rater subjectivity to allow any confidence to be placed in results based on this assessment method alone. It was believed that arriving at a final (subjective) rating based on three other subjective ratings would severely limit any conclusions drawn from the current study.

Further, as hypothesis 2 was formulated on the premise that human factors affect search success, it would seem more important to measure, as far as possible, the thinking processes that lead to a particular search outcome. That is, rather than assign a rating to a search outcome, it would be more illuminating to rate each search on a number of quantifiable behaviours which in combination achieved an effective search strategy.

A Ratings Sheet (see Appendix 10) was designed to measure twelve variables relevant to the development of a suitable search strategy. The Ratings Sheet enabled recording of data for: Number of Concepts; Number of Inappropriate Concepts; Number of Databases (Relevant, Irrelevant and Total); Number of Synonyms; Number of Reformulations; Use of Truncation; Use of Boolean Operators; Suitability of Search Strategies; Self-evaluation of Search Success; and Search Success. These variables were rated for all three search topics.
By analysing both search strategy and search outcome, it was possible to achieve a much more objective scoring of participants’ assignments than would have been possible if search outcome were the only measure.

Seven variables were assessed by counting the frequency of their occurrence; for example, the Number of Concepts (listed in search histories that were printed out with the assignments) was counted for each search topic attempted. The Use of Truncation was noted for each topic as either "correct", "incorrect", "mixed" (examples of both correct and incorrect usage); or "not used". The Use of Boolean Operators was recorded for each topic as falling into one of the following categories: "AND"; "OR"; "NOT"; "AND, OR"; "AND, OR, NOT"; and "AND, NOT". Participants were asked to self-rate their search success for each of the three search topics; the options available were: "I couldn’t find any useful information"; "Not very useful"; "Quite useful"; and "Very useful". The overall Search Strategy for the topic was rated as either "suitable" or "unsuitable". The final variable was a (necessarily) subjective judgement of Overall Search Success, based on Source, Currency and Relevance of items retrieved.

7.2.2.2 Variables Determined by Frequency

Data were analysed at both individual topic level, and all topics combined, for two reasons. Firstly, the research topics were designed to test varying levels of search difficulty. Topic 1 was quite complex; Topic 2 was straightforward; and Topic 3 was the most complex, requiring identification of concepts not explicitly stated in the question in order to answer the question successfully. Analysing the different responses of each subject to these different levels of search difficulty was therefore highly desirable.

Secondly, data for subjects who had attempted all three search topics was combined in order to ascertain if there were any consistent search patterns emerging. The researcher expected that such patterns would be very small,
Table 7-14: Descriptive Statistics for Variables Determined by Frequency, by Topic

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>Mode</th>
<th>SD</th>
<th>Range</th>
<th>Variance</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOPIC 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. concepts</td>
<td>184</td>
<td>2.918</td>
<td>3</td>
<td>1.338</td>
<td>17 (1-18)</td>
<td>1.791</td>
<td>7.866</td>
<td>88.342</td>
</tr>
<tr>
<td>No. inappropriate concepts</td>
<td>176</td>
<td>.352</td>
<td>0</td>
<td>.535</td>
<td>30 (0-30)</td>
<td>.287</td>
<td>1.405</td>
<td>2.374</td>
</tr>
<tr>
<td>No. relevant databases</td>
<td>141</td>
<td>1.922</td>
<td>2</td>
<td>1.153</td>
<td>7 (0-7)</td>
<td>1.330</td>
<td>1.799</td>
<td>5.078</td>
</tr>
<tr>
<td>No. irrelevant databases</td>
<td>70</td>
<td>.929</td>
<td>0</td>
<td>2.349</td>
<td>16 (0-16)</td>
<td>5.517</td>
<td>4.669</td>
<td>26.142</td>
</tr>
<tr>
<td>Total databases</td>
<td>164</td>
<td>3.280</td>
<td>2</td>
<td>3.691</td>
<td>30 (0-30)</td>
<td>13.626</td>
<td>4.165</td>
<td>23.026</td>
</tr>
<tr>
<td>No. synonyms</td>
<td>154</td>
<td>.506</td>
<td>0</td>
<td>.895</td>
<td>4 (0-4)</td>
<td>.801</td>
<td>2.032</td>
<td>3.790</td>
</tr>
<tr>
<td>No. reformulations</td>
<td>141</td>
<td>4.738</td>
<td>1</td>
<td>4.274</td>
<td>18 (0-18)</td>
<td>18.266</td>
<td>1.405</td>
<td>2.374</td>
</tr>
<tr>
<td><strong>TOPIC 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. concepts</td>
<td>180</td>
<td>2.628</td>
<td>3</td>
<td>.634</td>
<td>4 (0-4)</td>
<td>.403</td>
<td>-.957</td>
<td>1.414</td>
</tr>
<tr>
<td>No. inappropriate concepts</td>
<td>173</td>
<td>.197</td>
<td>0</td>
<td>.399</td>
<td>1 (0-1)</td>
<td>.159</td>
<td>1.541</td>
<td>.378</td>
</tr>
<tr>
<td>No. relevant databases</td>
<td>74</td>
<td>2.351</td>
<td>2</td>
<td>1.297</td>
<td>6 (0-6)</td>
<td>1.683</td>
<td>1.053</td>
<td>.728</td>
</tr>
<tr>
<td>No. irrelevant databases</td>
<td>73</td>
<td>.877</td>
<td>0</td>
<td>2.333</td>
<td>16 (0-16)</td>
<td>5.443</td>
<td>5.065</td>
<td>28.930</td>
</tr>
<tr>
<td>Total databases</td>
<td>165</td>
<td>3.436</td>
<td>2</td>
<td>2.706</td>
<td>19 (1-20)</td>
<td>7.321</td>
<td>3.101</td>
<td>13.853</td>
</tr>
<tr>
<td>No. synonyms</td>
<td>158</td>
<td>.430</td>
<td>0</td>
<td>.699</td>
<td>3 (0-3)</td>
<td>.489</td>
<td>1.668</td>
<td>2.461</td>
</tr>
<tr>
<td>No. reformulations</td>
<td>140</td>
<td>3.750</td>
<td>1</td>
<td>3.429</td>
<td>20 (0-20)</td>
<td>11.757</td>
<td>1.909</td>
<td>4.625</td>
</tr>
<tr>
<td><strong>TOPIC 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. concepts</td>
<td>177</td>
<td>2.294</td>
<td>2</td>
<td>.667</td>
<td>3 (1-4)</td>
<td>.446</td>
<td>.065</td>
<td>-.156</td>
</tr>
<tr>
<td>No. inappropriate concepts</td>
<td>163</td>
<td>.589</td>
<td>1</td>
<td>.564</td>
<td>2 (0-2)</td>
<td>.318</td>
<td>.271</td>
<td>-.837</td>
</tr>
<tr>
<td>No. relevant databases</td>
<td>57</td>
<td>1.772</td>
<td>1</td>
<td>1.581</td>
<td>7 (0-7)</td>
<td>2.501</td>
<td>1.261</td>
<td>1.629</td>
</tr>
<tr>
<td>No. irrelevant databases</td>
<td>60</td>
<td>1.767</td>
<td>2</td>
<td>1.640</td>
<td>8 (0-8)</td>
<td>2.690</td>
<td>1.795</td>
<td>4.286</td>
</tr>
<tr>
<td>Total databases</td>
<td>141</td>
<td>3.489</td>
<td>3</td>
<td>3.042</td>
<td>19 (1-20)</td>
<td>9.252</td>
<td>2.649</td>
<td>9.072</td>
</tr>
<tr>
<td>No. synonyms</td>
<td>147</td>
<td>.721</td>
<td>0</td>
<td>1.078</td>
<td>8 (0-8)</td>
<td>1.161</td>
<td>2.874</td>
<td>14.053</td>
</tr>
<tr>
<td>No. reformulations</td>
<td>131</td>
<td>4.282</td>
<td>1</td>
<td>3.899</td>
<td>25 (0-25)</td>
<td>15.204</td>
<td>2.224</td>
<td>7.256</td>
</tr>
</tbody>
</table>
as it was expected that they would vary with the degree of difficulty of search topic.

Table 7-14 summarises descriptive statistics for the seven variables determined by frequency of occurrence, for each search topic separately. The data summarised in Table 7-14 indicates that with the exception of two variables for Topic 3 (Number of Concepts and Number of Inappropriate Concepts), data did not approximate the normal curve.

Table 7-15 indicates that for the combined data for all search topics, two of the seven variables approximated the normal distribution: Number of Inappropriate Concepts; and Number of Relevant Databases.

Table 7-15: Descriptive Statistics for Variables Determined by Frequency - All Search Topics Combined

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
<th>Variance</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. concepts</td>
<td>165</td>
<td>7.842</td>
<td>1.780</td>
<td>18 (3-21)</td>
<td>3.170</td>
<td>2.078</td>
<td>17.645</td>
</tr>
<tr>
<td>No. inappropriate concepts</td>
<td>154</td>
<td>1.130</td>
<td>.968</td>
<td>4 (0-4)</td>
<td>.937</td>
<td>.524</td>
<td>-.474</td>
</tr>
<tr>
<td>No. relevant databases</td>
<td>49</td>
<td>6.490</td>
<td>3.097</td>
<td>12 (2-14)</td>
<td>9.588</td>
<td>.717</td>
<td>-.255</td>
</tr>
<tr>
<td>No. irrelevant databases</td>
<td>49</td>
<td>4.184</td>
<td>6.163</td>
<td>34 (0-34)</td>
<td>37.986</td>
<td>3.663</td>
<td>15.073</td>
</tr>
<tr>
<td>Total no. databases</td>
<td>129</td>
<td>10.388</td>
<td>7.075</td>
<td>40 (3-43)</td>
<td>50.052</td>
<td>2.221</td>
<td>6.060</td>
</tr>
<tr>
<td>No. synonyms</td>
<td>130</td>
<td>1.615</td>
<td>2.081</td>
<td>14 (0-14)</td>
<td>4.332</td>
<td>2.617</td>
<td>10.266</td>
</tr>
<tr>
<td>No. reformulations</td>
<td>113</td>
<td>13.442</td>
<td>9.588</td>
<td>46 (3-49)</td>
<td>91.927</td>
<td>1.571</td>
<td>2.822</td>
</tr>
</tbody>
</table>

The descriptive statistics summarised above suggested that t-tests for equality of means between the experimental and control groups should be performed on Topic 3, Number of Concepts and Number of Inappropriate Concepts; and on Inappropriate Concepts and Relevant Databases for the combined search topics. Differences between the experimental and control
groups in the remaining data for each separate search topic were determined by the non-parametric Mann-Whitney U - Wilcoxon Rank Sum W Test. Statistically significant results appear in Table 7-16 below.

Table 7-16: Significant Differences between Experimental and Control Groups on Variables Determined by Frequency

<table>
<thead>
<tr>
<th>Variable - Individual Search Topic</th>
<th>Test for Mean Difference (two tailed)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1: Number of Concepts</td>
<td>Mann-Whitney U</td>
<td>p = .0366</td>
</tr>
<tr>
<td>Topic 2: Number of Concepts</td>
<td>Mann-Whitney U</td>
<td>p = .0009</td>
</tr>
<tr>
<td>Topic 3: Number of Inappropriate Concepts</td>
<td>t-test</td>
<td>p = .033</td>
</tr>
<tr>
<td>Topic 3: Total number of databases</td>
<td>Mann-Whitney U</td>
<td>p = .0185</td>
</tr>
</tbody>
</table>

For Search Topics 1 and 2, the experimental group used significantly more concepts in planning their search strategies than did the control group. The experimental group mean for Topic 1 was 3.15; the control group mean for Topic 1 was 2.74 (p = .0366). The experimental group mean for Topic 2 was 2.80; the control group mean for Topic 2 was 2.47 (p = .0009). These results suggest that the focus of the Module (delivered to the experimental group in week 2 of semester) on the need to identify as many concepts as possible when designing search strategies was appropriate.

For Topic 3, the experimental group mean (.6944) was significantly higher than the control group mean (.5055) for Number of Inappropriate Concepts (p = .033). It had been expected that the experimental group would make fewer errors than the control group in terms of identification of concepts.
However, the researcher believes the higher number of inappropriate concepts used by the experimental group is explained by the fact that the experimental group had been encouraged to identify as many search terms as possible in their module instruction - possibly, in the effort to identify as many concepts as they could, the number of inappropriate concepts also rose.

This result may not have occurred in Topic 1 because concepts were clearly stated in the question - and the experimental group identified more of them. In Topic 2, it was not necessary to identify numerous alternative concepts as the question was straightforward. This view is supported by the data, which show that the mean number of reformulations (3.750) and the mean number of synonyms (.430) for Topic 2 were lower than for both Topic 1, and Topic 3 (see Table 7-14). 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.

The experimental group also used significantly more databases in their search on Topic 3 than did the control group; again, this may have been due to the emphasis in the Module on the need to select the right databases. The Number of Inappropriate Databases used in Topic 3 for the experimental and control groups combined (mean = 1.767) was higher than the mean for Inappropriate Databases on both Topic 1 (mean = .929) and Topic 2 (mean = .877). Once more, this may reflect the varying difficulties of the search topics.

Means for the experimental group use of concepts (appropriate and inappropriate), reformulations, databases (relevant, irrelevant and total), and synonyms were in general higher than the control group means. Of these 21 variables (seven variables for each of three topics), the experimental group mean was higher on 16 variables (76%).
When all search topics were combined, results indicated that there was a significant difference between performance by the experimental group and the control group on three variables: Number of Concepts, Number of Inappropriate Concepts and Number of Synonyms (Table 7-16).

On the remaining four variables - Number of Relevant Databases, Number of Irrelevant Databases, Total Number of Databases and Number of Reformulations, the experimental group means were always slightly higher than the control group mean, although the differences were not statistically significant.

Correlates
There were a number of significant positive correlations between the variables determined by frequency. Number of Reformulations was correlated significantly with Number of Inappropriate Concepts for all topics (Topic 1: $r = 0.2778; p = .009$; Topic 2: Spearman's $r = 0.2258; p = .034$; and Topic 3: $r = 0.3601; p = .002$); and with Number of Concepts on Topic 3 ($r = 0.2724; p = .013$). Number of Reformulations was correlated with Number of Synonyms for all topics (Topic 1: $r = 0.4611; p = .000$; Topic 2: $r = 0.4870; p = .000$; Topic 3: $r = 0.5170; p = .000$). Number of Reformulations was also correlated with the Number of Databases for Topic 3 ($r = 0.2169; p = .039$). Finally, Number of Concepts and Number of Synonyms were correlated for Topic 2 ($r = 0.2978; p = .003$).

When all topics were combined, there were also significant correlations between: Number of Concepts and Total Number of Databases ($r = .1781; p = .023$); Number of Concepts and Total Relevant Databases ($r = .4420; p = .001$); and Number of Synonyms and Total Number of Databases ($r = .1894; p = .028$).
The correlation found on all Topics between Number of Reformulations and either Number of Concepts or Inappropriate Concepts, and Number of Synonyms, is not surprising, as the more keywords identified, the more combinations (reformulations) of those terms that are possible.

7.2.2.3 Other Variables

Other variables determining success on the Information Retrieval Assignment were Use of Truncation; Use of Boolean Operators; Self Evaluation of Search Success; Use of Suitable Strategies; and Overall Search Success. These variables are discussed in detail below.

Levels of measurement for these variables differed according to their type; the scales used for measurement are set out in Table 7-17 below. The type of scale determined the statistical analysis appropriate for the variable.
Table 7-17: Descriptive Statistics for Search Strategy Variables Measured on Nominal and Ordinal Scales

<table>
<thead>
<tr>
<th>Variable</th>
<th>Measurement</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truncation</td>
<td>Nominal</td>
<td>1 = correct</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 = incorrect</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 = mixed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 = not used</td>
</tr>
<tr>
<td>Boolean Operators</td>
<td>Nominal</td>
<td>1 = and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 = or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 = not</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 = and, or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 = and, or, not</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 = and, not</td>
</tr>
<tr>
<td>Use of Suitable Search Strategies</td>
<td>Nominal</td>
<td>1 = appropriate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 = inappropriate</td>
</tr>
<tr>
<td>Self-evaluation of search success</td>
<td>Ordinal</td>
<td>0 = not successful</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = some success</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 = quite successful</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 = very successful</td>
</tr>
<tr>
<td>Overall Search Success</td>
<td>Ordinal</td>
<td>0 = inadequate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = marginally adequate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 = adequate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 = good</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 = superior</td>
</tr>
</tbody>
</table>

*Truncation*

In information retrieval, truncation refers to the use of a word stem followed by an asterisk or other symbol (depending on the database) in the search to ensure that all possible word endings are retrieved; for example, the search term `clon*` would retrieve articles which contained the words clone, cloning and cloned. The use of truncation therefore enables a more comprehensive search on a topic to be performed than if it is not used - if all possible word endings are retrieved, then more items referring to the target concept will be retrieved; that is, search recall will be increased.

Table 7-18 summarises the use of truncation for Topic 1, as a function of treatment (experimental group or control group).
Table 7-18: Topic 1: Use of Truncation as a Function of Treatment

<table>
<thead>
<tr>
<th></th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Correct use of truncation</td>
<td>10</td>
<td>14.5</td>
</tr>
<tr>
<td>Incorrect use of truncation</td>
<td>7</td>
<td>10.1</td>
</tr>
<tr>
<td>Mixed use of truncation</td>
<td>10</td>
<td>14.5</td>
</tr>
<tr>
<td>Truncation not used</td>
<td>40</td>
<td>58.0</td>
</tr>
<tr>
<td>Information on truncation not</td>
<td>2</td>
<td>2.9</td>
</tr>
<tr>
<td>provided for this Topic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>69</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 7-18 indicates that 148 participants in total provided information on truncation for Topic 1; of these, 69 (46.6%) belonged to the experimental group and 79 (53.37%) to the control group.

In every condition in which truncation was used (correct, incorrect, mixed), the experimental group performed better than the control group. Of the experimental group, 14.5% used correct truncation, compared with 11.4% of the control group. More subjects in the experimental group (14.5%), compared with 6.3% in the control group, used mixed truncation (that is, truncation use that was sometimes correct eg run* for running; and sometimes incorrect eg altitudes*). Of the experimental group, 10.1% used truncation incorrectly, compared with 5.1% of the control group. Comparing any use of truncation (correct, incorrect, mixed), to no use, a chi-square test indicated the difference between experimental and control groups was significant (p = .029). The difference in use of truncation between experimental and control treatments was highly significant (Pearson chi-square; p = 0.00149).

The fact that more mixed, and incorrect, truncation, were used by the experimental group could indicate that having being made aware in the
Module of the importance of the use of truncation, the experimental group attempted to use it more often than did the control group, even though its use was not always correct. This conclusion is supported by the fact that 58% of the experimental group, compared with 74.7% of the control group, used no truncation at all.

Table 7-19 summarises truncation use for Topic 2, as a function of treatment. It indicates that 150 participants in total provided information on truncation for Topic 2; of these, 71 (47.33%) belonged to the experimental group and 79 (52.66%) to the control group.

Table 7-19: Topic 2: Use of Truncation as a Function of Treatment

<table>
<thead>
<tr>
<th></th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct use of truncation</td>
<td>24 (33.8%)</td>
<td>24 (30.4%)</td>
</tr>
<tr>
<td>Incorrect use of truncation</td>
<td>3 (4.2%)</td>
<td>2 (2.5%)</td>
</tr>
<tr>
<td>Mixed use of truncation</td>
<td>10 (14.1%)</td>
<td>4 (5.1%)</td>
</tr>
<tr>
<td>Truncation not used</td>
<td>32 (45.1%)</td>
<td>47 (59.5%)</td>
</tr>
<tr>
<td>Information on truncation not provided for this Topic</td>
<td>2 (2.8%)</td>
<td>2 (2.5%)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>71 (100%)</td>
<td>79 (100%)</td>
</tr>
</tbody>
</table>

As with Topic 1, the experimental group performed better than the control group in every category of truncation use (correct, incorrect, mixed).

Again, as with Topic 1, fewer participants in the experimental group (45.1%) used no truncation at all, compared with 59.5% of the control group, but results were not significant.
Table 7-20 indicates that 138 participants in total provided information on truncation for Topic 3; of these, 60 (43.47%) belonged to the experimental group and 79 (57.24%) to the control group.

Table 7-20: Topic 3: Use of Truncation as a Function of Treatment

<table>
<thead>
<tr>
<th></th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Correct use of truncation</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>Incorrect use of truncation</td>
<td>8</td>
<td>13.3</td>
</tr>
<tr>
<td>Mixed use of truncation</td>
<td>2</td>
<td>3.3</td>
</tr>
<tr>
<td>Truncation not used</td>
<td>35</td>
<td>58.3</td>
</tr>
<tr>
<td>Information on truncation not provided for this Topic</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>60</td>
<td>100</td>
</tr>
</tbody>
</table>

As with Topics 1 and 2, the experimental group was ahead of the control group in every condition in which truncation was used (correct, incorrect, mixed), but results were not statistically significant.

Again, as with Topics 1 and 2, fewer participants in the experimental group (58.3%) used no truncation at all, compared with 71.8% of the control group.

For all three search topics, there is a consistent use by the experimental group of more correct, mixed, and incorrect, truncation than the control group. This difference was statistically significant on Topic 1. It is likely that the experimental Module’s emphasis on the efficacy of truncation in the design of search strategies has led to the experimental group attempting truncation use more often than the control group, even though its use is not always correct. This conclusion is supported by the fact that for all search topics,
fewer subjects in the experimental group, compared with the control group, used no truncation at all.

When comparing use of truncation between the three search topics, it is evident that on Topic 2, both the experimental group (33%) and the control group (30%) used more correct truncation than they did in either Topic 1 (14.5% experimental, 11.4% control) or Topic 2 (20% experimental, 14% control). Moreover, the percentage of subjects in the "no truncation" condition for both the experimental group (45.1%), and the control group (59.5%), was substantially lower for Topic 2 than it was for either Topic 1 (58% experimental, 74.7% control), or Topic 3 (58.3% experimental, 71.8% control).

Topic 2 was the most straightforward of the three search topics. Concepts used were easy to identify, and easy to truncate (for example, run*; train*).

On all three search topics, there was approximately the same difference in use of truncation between the experimental group and the control group. This result suggests that for all search topics, the experimental group was attempting to apply truncation in the design of search strategies more than was the control group. This trend was maintained even when an easier topic (Topic 2) was attempted.

Table 7-21 provides data on the Use of Truncation for all topics combined. It indicates that 31 subjects in the experimental group (26.27%), and 30 subjects in the control group (20.05%), used truncation correctly on at least one of the three search topics. Ninety per cent of the 31 experimental group subjects, and 90% of the 30 control group subjects, used truncation correctly on one or two search questions (percentages calculated by adding frequency of correct use of truncation for the treatment group, dividing it by the total number of subjects who provided information on truncation for all three search topics,
then multiplying the result by 100). Only subjects who provided information on their use of truncation for all three search topics are included in this analysis, in order to enable patterns of truncation use, if any, to be identified as a function of research treatment.

Table 7-21 Correct Use of Truncation as a Function of Treatment (combined analysis of all Search Topics)

<table>
<thead>
<tr>
<th>Correct use of Truncation:</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>- on one topic</td>
<td>19</td>
<td>16.1</td>
</tr>
<tr>
<td>- on two topics</td>
<td>9</td>
<td>7.6</td>
</tr>
<tr>
<td>- on three topics</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>Participants who did not use correct truncation, or did not provide truncation information on all three Topics</td>
<td>87</td>
<td>73.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>118</td>
<td>100</td>
</tr>
</tbody>
</table>

For those subjects who provided truncation information for all three search topics, there was no difference in correct truncation usage between the experimental and the control groups. The three experimental group subjects who used correct truncation on all topics had a mean score on the pre-test of electronic database knowledge of 11. The mean score on that pre-test for the control group subjects who used correct truncation on all topics was 13. It may be that, even though the experimental group subjects’ electronic database knowledge was not as good as the control groups’, the experimental Module may have encouraged the use of truncation.

Table 7-22 indicates that 16 subjects in the experimental group (13.55%), and 9 subjects in the control group (6.61%), used mixed truncation on at least one of the search topics. Only subjects who provided information on their use of
truncation for all three search topics are included in this analysis, in order to enable patterns of truncation use, if any, to be identified as a function of research treatment.

Table 7-22: Mixed Use of Truncation as a Function of Treatment (combined analysis of all Search Topics)

<table>
<thead>
<tr>
<th>Mixed use of Truncation (some correct, some incorrect):</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>- on one topic</td>
<td>11</td>
<td>9.3</td>
</tr>
<tr>
<td>- on two topics</td>
<td>4</td>
<td>3.4</td>
</tr>
<tr>
<td>- on three topics</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Participants who did not use mixed truncation, or did not provide truncation information on all three topics</td>
<td>102</td>
<td>86.4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>118</td>
<td>100</td>
</tr>
</tbody>
</table>

The fact that more mixed truncation was used by the experimental group could indicate that having being made aware in the Module of the importance of the use of truncation, the experimental group attempted to use it more often than did the control group, even though its use was not always correct.

Table 7-23 indicates that 14 subjects in the experimental group (11.86%), and 12 subjects in the control group (8.82%), attempted to use truncation, but used it incorrectly (eg altitudes*), on one or two of the search topics. No subjects used incorrect truncation on all three search topics. Only subjects who provided information on their use of truncation for all three search topics are included in this analysis, in order to enable patterns of truncation use, if any, to be identified as a function of research treatment.
Table 7-23: Incorrect Use of Truncation as a Function of Treatment (combined analysis of all Search Topics)

<table>
<thead>
<tr>
<th>Incorrect use of Truncation:</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>- on one topic</td>
<td>10</td>
<td>8.5</td>
</tr>
<tr>
<td>- on two topics</td>
<td>4</td>
<td>3.4</td>
</tr>
<tr>
<td>- on three topics</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Participants who did not use incorrect truncation, or did not provide truncation information on all three Topics</td>
<td>104</td>
<td>88.1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>118</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 7-24 indicates that 53 subjects in the experimental group (44.91%), and 74 subjects in the control group (54.41%), did not use truncation at all. Sixty five subjects in the experimental group (55%), and 62 subjects in the control group (45.58%), did not provide truncation information on all three search topics. Only subjects who provided information on their use of truncation for all three search topics are included in this analysis, in order to enable patterns of truncation use if any, as a function of research treatment, to be identified.

Table 7-24: Truncation Not Used as a Function of Treatment (combined analysis of all Search Topics)

<table>
<thead>
<tr>
<th>No Truncation used:</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>- on one topic</td>
<td>19</td>
<td>16.1</td>
</tr>
<tr>
<td>- on two topics</td>
<td>14</td>
<td>11.9</td>
</tr>
<tr>
<td>- on three topics</td>
<td>20</td>
<td>16.9</td>
</tr>
<tr>
<td>Participants who did not provide truncation information on all three Topics</td>
<td>65</td>
<td>55.1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>118</td>
<td>100</td>
</tr>
</tbody>
</table>
**Boolean Operators**

Boolean operators (AND, OR, NOT) are used to represent connections between concepts, and to limit information retrieved, in search strategy formulation. For example, if a student wanted to research the topic “Identify pollutants affecting estuaries in the Sydney region”, concepts relevant to the search (ignoring synonyms) would include *pollutants, estuaries* and *Sydney*. The relationship between these concepts would be defined by Boolean logic, and represented in the search by the logical connectors AND, OR and NOT.

One possible search strategy might be: pollut* NOT air AND Sydney. Using Boolean operators increases the efficiency of a search. The operator AND enables two or more concepts to be combined so that only articles in which all the required concepts appear are retrieved (this use of the word AND is contrary to the understanding of most people, who usually expect this word to expand a search, when in fact AND narrows a search). The operator OR enables synonyms to be searched (e.g., esturar* OR river), having the effect of widening a search (again, contrary to popular usage of the term, which suggests *narrowing*). The operator NOT excludes unnecessary articles (such as those about air pollution). In this way, Boolean operators increase search *precision*.

In the following three tables, the use of Boolean operators is summarised for each search topic separately, as a function of treatment (experimental or control). Not all subjects provided information on Boolean operators.

**Table 7-25: Topic 1: Use of Boolean Operators as a Function of Treatment**

<table>
<thead>
<tr>
<th></th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Use of “AND” operator</td>
<td>58</td>
<td>89.2</td>
</tr>
<tr>
<td>Use of “AND, OR”</td>
<td>7</td>
<td>10.8</td>
</tr>
<tr>
<td>operators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No data available</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>65</td>
<td>100</td>
</tr>
</tbody>
</table>
For Topic 1 (Table 7-25), with both experimental and control groups, use of the operator “AND” is high, and approximately of the same proportion. This is not surprising, as the default setting for search strategy input on the ERL databases is the “AND” operator - and there is no “no operator” option. More of the experimental group (10.8%), used the complex “AND, OR” combination, compared with 6.5% of the control group.

In the experimental Module, the use of Boolean operators had been discussed.

Table 7-26: Topic 2: Use of Boolean Operators as a Function of Treatment

<table>
<thead>
<tr>
<th></th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Use of “AND” operator</td>
<td>57</td>
<td>83.8</td>
</tr>
<tr>
<td>Use of “AND, OR” operators</td>
<td>9</td>
<td>13.2</td>
</tr>
<tr>
<td>Use of “NOT” operator</td>
<td>2</td>
<td>2.9</td>
</tr>
<tr>
<td>TOTAL</td>
<td>68</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 7-26 indicates that for Topic 2, as for Topic 1, the experimental group has used complex operators twice as frequently as the control group (13.2% of the experimental group has used “AND, OR”, compared with 6.7% of the control group). Results were not statistically significant.

Table 7-27: Topic 3: Use of Boolean Operators as a Function of Treatment

<table>
<thead>
<tr>
<th></th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Use of “AND” operator</td>
<td>45</td>
<td>76.3</td>
</tr>
<tr>
<td>Use of “OR” operator</td>
<td>2</td>
<td>3.4</td>
</tr>
<tr>
<td>Use of “AND, OR” operators</td>
<td>12</td>
<td>20.3</td>
</tr>
<tr>
<td>No data available</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>59</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 7-27 shows that for Topic 3, as for Topics 1 and 2, the experimental group has used more complex operators than the control group (20.3% of the experimental group has used “AND, OR”, compared with only 5.4% of the control group). To enable a chi-square test to be carried out, results were recoded to two values: use of “AND” operator only; or use of complex operators (all other combinations of operators). The results were highly statistically significant (Pearson chi-square value 8.271; df 1; p = 0.004).

The use of complex Boolean operators by the experimental group was higher on all three topics; significantly so on Topic 3 – the most difficult topic. The Module appears to have been effective in encouraging subjects to use complex operators in the design of their searches.

Search Strategies
Participants were rated on the suitability or otherwise of their search strategies for the three research topics. Strategies were coded as either suitable (“yes”), or unsuitable (“no”). A suitable strategy was considered to be one in which search concepts were appropriate to the topic; for example, for Topic 1, a suitable strategy might have been “literacy AND higher education AND Australia”. An unsuitable strategy might have been “higher AND education”; or “high school AND literacy”. Selection of databases was not considered in the assessment of search strategy formulation, as suitability of databases had already been considered under separate criteria.
Table 7-28: Topic 1: Suitability of Search Strategy as a Function of Treatment

<table>
<thead>
<tr>
<th>Search strategy suitable</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Yes</td>
<td>32</td>
<td>47.8</td>
</tr>
<tr>
<td>No</td>
<td>33</td>
<td>49.8</td>
</tr>
<tr>
<td>No data</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>67</td>
<td>100</td>
</tr>
</tbody>
</table>

For Topic 1 (Table 7-28), the experimental group (47.8%) chose suitable search strategies more often than did the control group (39.5%).

Table 7-29: Topic 2: Suitability of Search Strategy as a Function of Treatment

<table>
<thead>
<tr>
<th>Search strategy suitable</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Yes</td>
<td>58</td>
<td>85.3</td>
</tr>
<tr>
<td>No</td>
<td>10</td>
<td>14.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>68</td>
<td>100</td>
</tr>
</tbody>
</table>

For Topic 2 (Table 7-29), most participants (both experimental - 85.3%, and control - 84.3%), were able to formulate suitable search strategies. This result is what would be expected, as Topic 2 was a straightforward search topic, requiring a simple combination of three unambiguous concepts.

Table 7-30: Topic 3: Suitability of Search Strategy as a Function of Treatment

<table>
<thead>
<tr>
<th>Search strategy suitable</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Yes</td>
<td>24</td>
<td>42.1</td>
</tr>
<tr>
<td>No</td>
<td>31</td>
<td>54.4</td>
</tr>
<tr>
<td>No data</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>57</td>
<td>100</td>
</tr>
</tbody>
</table>
For Topic 3 (Table 7-30), slightly more of the experimental group (42.1%) than the control group (39.7%) were able to formulate a suitable search strategy. Topic 3 was the most complex of the three topics.

Table 7-31: Topics 1, 2 & 3 Combined: Suitability of Search Strategy as a Function of Treatment

<table>
<thead>
<tr>
<th>Search strategies</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>3 strategies correct</td>
<td>12</td>
<td>25.5</td>
</tr>
<tr>
<td>2 strategies correct</td>
<td>17</td>
<td>36.2</td>
</tr>
<tr>
<td>1 strategy correct</td>
<td>15</td>
<td>31.9</td>
</tr>
<tr>
<td>0 strategies correct</td>
<td>3</td>
<td>6.4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>47</td>
<td>100</td>
</tr>
</tbody>
</table>

Combined data for the participants who attempted all three search topics (Table 7-31) indicates that the experimental group (25.5%) was able to select suitable search strategies on all three topics more often than the control group (17.4%). The control group (8.7%) used incorrect strategies on all three topics more than did the experimental group (6.4%); but differences were not significant.

Search Success

For each research topic, every article for which a citation was provided was assessed for relevance to the topic. Relevance was based on currency (ie year of publication); source (ie academic journal or generalist magazine); and relationship to the topic. For each article, a score for relevance was given (0 = “Inadequate”; 1 = “Marginally adequate”; 2 = “Adequate”; 3 = “Good”; 4 = “Superior”).

Search success for each topic was evaluated by considering how many articles were found, and their relevance to the topic. For Topics 1 and 2, four articles had been stipulated; for Topic 3, ten. A rating for the search success...
for each topic was then given: 0 = “Inadequate”; 1 = “Marginally adequate”; 2 = “Adequate”; 3 = “Good”; and 4 = “Superior”.

Table 7-32 below summarises results for Topic 1 on search success.

Table 7-32: Topic 1: Search Success as a Function of Treatment

<table>
<thead>
<tr>
<th>Search success</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Inadequate</td>
<td>55</td>
<td>88.7</td>
</tr>
<tr>
<td>Marginally adequate</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>Adequate</td>
<td>3</td>
<td>4.8</td>
</tr>
<tr>
<td>Good</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL</td>
<td>62</td>
<td>100</td>
</tr>
</tbody>
</table>

For Topic 1, nearly all participants’ search results (that is, the collection of abstracts submitted) were rated as “Inadequate” (experimental group 88.7%; control group 87.2%), despite the fact that the search strategies they had formulated were appropriate. Some of the reasons for this appear to have been computer unavailability, and computer server failure; many participants did not choose appropriate databases. This may have been influenced by the lack of clear identification of database contents on the website. These issues are discussed in Chapter 6.

Further, the limitation in the Topic 1 question that articles from 1995 be found, made the question quite difficult, as “highly relevant” articles for the topic were not easy to locate. Nevertheless, these circumstances enabled detailed information on search reformulation patterns to be gathered, as subjects in general used as many search combinations as they could think of in order to find relevant information.
For Topic 2 (Table 7-33), slightly more of the experimental group (52.9%), then the control group (46.3%), were rated as “Inadequate”. However, there were more participants from the control group (29.3%) in the “Marginally adequate” condition than participants from the experimental group (18.6%). The experimental group performed slightly better than the control group on the conditions “Adequate” and “Good” combined (experimental group 28.5%; control group 24.4%). So for Topic 2, the experimental group performed slightly better than the control group in terms of overall search success.

For Topic 3 (Table 7-34), again the experimental group performed better than did the control group; 36.1% of the experimental group were rated “Marginally adequate” and above; whereas 29.6% of the control group fell...
into those categories (however, no control group participants were rated "Superior").

For the condition Search Success then, the experimental group performed slightly better than the control group on Topics 2 and 3; both groups performed poorly on Topic 1. On this topic, the poor performance was probably due to the difficulty in obtaining the specified “highly relevant” articles from 1995. Several students reported that, rather than expanding their search to other years to find relevant articles, they continued to reformulate their searches, focusing on the one year, in order to find articles.

Topic 2 on the other hand, was more straightforward, and the rise in search success, particularly for the experimental group, reflects this. However, apart from the computer difficulties that hindered search success, the researcher observes that for Topic 2, many students found the same articles - several of which were not in English. The articles were rated “Inadequate”. Depending on which database these articles were accessed from, the language of the article was, or was not, apparent. Further, although there were many articles accessible on Topic 2, a number of them were not from scholarly sources, and were also rated “Inadequate”.

Topic 3 perhaps provides the best indication of participants' search success. The search required the correct identification and combination of several concepts, and the correct choice of several databases, as did Topic 1, but there was much more information available. However, search success rate was still not very high. The inclusion of citations from non-scholarly sources appeared to be the major factor inhibiting overall search success.

In conclusion, Search Success overall was not very good, as approximately 50% of subjects' search success was rated as inadequate for all search topics. Search success, although influenced by search strategy formulation, is not an
inevitable consequence of effective concept and synonym identification; search efficiency (use of truncation and Boolean operators); and strategy design.

Other factors are also important, for example, the choice of database (that is, the ability to locate relevant material); and the assessment of credibility and relevance of materials located (that is, the ability to critically evaluate material located). Therefore, any effective information retrieval instruction needs to ensure that these factors are also carefully explained to students.

Participant Self-evaluation of Search Success

Considering the researcher ratings of participant search success discussed above, participant self-evaluation of search success was particularly interesting. As part of their Information Retrieval Assignment, participants were asked to rate their search results as “Very useful”; “Quite useful”; “Not very useful”; or “I couldn’t find any useful information”. Results are set out in Table 7-35 below.

Table 7-35: Topic 1: Participant Self-evaluation of Search Success as a Function of Treatment

<table>
<thead>
<tr>
<th>Self-evaluation</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Couldn’t find any useful information</td>
<td>29</td>
<td>37.2</td>
</tr>
<tr>
<td>Not very useful</td>
<td>34</td>
<td>43.6</td>
</tr>
<tr>
<td>Quite useful</td>
<td>12</td>
<td>15.4</td>
</tr>
<tr>
<td>Very useful</td>
<td>3</td>
<td>3.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>78</td>
<td>100</td>
</tr>
</tbody>
</table>

For Topic 1, 80.8% of the experimental group considered that either they “Couldn’t find any useful information”, or that that information was “Not very useful”. This figure is close to the researcher’s evaluation of their search success - 88.7% of the experimental group’s searches were rated
"Inadequate". On the other hand, 68.1% of the control group considered that for Topic 1, they either "Couldn't find any useful information", or the information was "Not very useful". The researcher's evaluation of the control group's search success was rather different - 87.2% of the search results were considered "Inadequate". These results suggest that the experimental group rated their search success more realistically than did the control group.

Table 7-36: Topic 2: Participant Self-evaluation of Search Success as a Function of Treatment

<table>
<thead>
<tr>
<th>Self-evaluation</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Couldn't find any useful information</td>
<td>19</td>
<td>24.1</td>
</tr>
<tr>
<td>Not very useful</td>
<td>22</td>
<td>27.8</td>
</tr>
<tr>
<td>Quite useful</td>
<td>30</td>
<td>38.0</td>
</tr>
<tr>
<td>Very useful</td>
<td>8</td>
<td>10.1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>79</td>
<td>100</td>
</tr>
</tbody>
</table>

For Topic 2 (Table 7-36), 51.9% of the experimental group considered that either they "Couldn't find any useful information", or that that information was "Not very useful". Again, this figure is close to the researcher's evaluation of their search success - 52.9% of the experimental group's searches were rated "Inadequate". Similarly, 50.1% of the control group considered that for Topic 2, they either "Couldn't find any useful information", or the information was "Not very useful". The researcher's evaluation of the control group's search success was 46.3% "Inadequate". These results suggest that for Topic 2, both the experimental group and the control group had self-ratings comparable to those of the researcher. Topic 2 was the most straightforward research topic.
Table 7-37: Topic 3: Participant Self-evaluation of Search Success as a Function of Treatment

<table>
<thead>
<tr>
<th>Self-evaluation</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>Couldn't find any useful info.</td>
<td>15</td>
<td>21.1</td>
</tr>
<tr>
<td>Not very useful</td>
<td>19</td>
<td>26.8</td>
</tr>
<tr>
<td>Quite useful</td>
<td>33</td>
<td>46.5</td>
</tr>
<tr>
<td>Very useful</td>
<td>4</td>
<td>5.6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>71</td>
<td>100</td>
</tr>
</tbody>
</table>

For Topic 3 (Table 7-37), 47.9% of the experimental group considered that either they “Couldn't find any useful information”, or that the information was “Not very useful”. This figure is different from the researcher’s evaluation of their search success - 63.9% of the experimental group’s searches were rated “Inadequate”. Similarly, 56.1% of the control group considered that for Topic 3, they either “Couldn’t find any useful information”, or the information was “Not very useful”. The researcher’s evaluation of the control group’s search success was different - 70.4% of the search results were considered “Inadequate”. These results suggest that both the experimental group and the control group over-rated their search success. Even though subjects found articles that were relevant, they were often not from credible sources. For example, articles from popular computer magazines were not considered by the researcher to be “adequate”. Such magazine articles were typically found on the databases ABI/Inform Fulltext, and Computer ASAP. Articles were usually by an anonymous author, were one page long, and the title of the magazine would be something like “Computerworld”.

Taken individually, and compared with researcher ratings of success, the three search topics all resulted in different relationships between self-evaluation of search success, and rater evaluation of search success. Each search topic was of a different level of difficulty, and each had unique
characteristics. For Topic 1, the experimental group and the rater scores were similar; the control group over-rated their success. Topic 1 was a difficult topic in that relevant material for the year stipulated - 1995 - was hard to locate. The experimental group had been instructed about elements of successful searches in the Module they had received in tutorials in Week 2, and it is likely that this assisted them to come to a more realistic assessment of their search success than did the control group.

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. 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; that is, search recall was high, and resulted in participant perception of search success. However, search precision was not high. Precision and credibility of sources were factors considered by the researcher, but apparently not by the participants, even though credibility of sources had been discussed in the experimental Module. Examples of credible and popular sources were given verbally, but it is possible that if the two slides dealing with credible sources in the Module had then been followed by slides showing examples of citations of credible and popular sources as they appear on electronic databases, the point may have been made more strongly. Further, it may be that after not finding many relevant articles for the first two search topics, participants over-rated their success in the last topic based simply on the larger number of relevant citations; at that point, they may not have been interested in precision and credibility.

The researcher rated the experimental group higher than the control group in overall Search Success on Topics 2 and 3, which indicates that overall, that participants in the control group over-rated their search success. The phenomenon of the "false positive" in novice end-user searching may explain this result. Self-evaluation of search success is an example of a
metacognitive behaviour of the type that is exhibited by "formal" thinkers, or expert searchers. There were no gender differences in self-evaluation of search success.

Chi-square analysis indicated a significant difference between experimental and control groups on self-evaluation for Topic 1, but not for Topics 2 and 3 (Topic 1: Pearson chi square; p = 0.05).

Hypothesis 2 - Conclusion

Analysis of results relating to Hypothesis 2: "There is a difference between experimental and control groups on search performance" proved to be lengthy and complex. The Information Retrieval Assignment consisted of three search topics, and for each of these topics, twelve variables were measured. Results indicated significant differences between the experimental group and the control group on the variables summarised in Table 7-38 below:

Table 7-38: Significant differences between experimental and control groups for each search topic

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>Variable</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1</td>
<td>Number of concepts</td>
<td>.0366</td>
</tr>
<tr>
<td></td>
<td>Use of truncation</td>
<td>.00149</td>
</tr>
<tr>
<td></td>
<td>Self-evaluation of search success</td>
<td>.05</td>
</tr>
<tr>
<td>Topic 2</td>
<td>Number of concepts</td>
<td>.0009</td>
</tr>
<tr>
<td>Topic 3</td>
<td>Number of inappropriate concepts</td>
<td>.033</td>
</tr>
<tr>
<td></td>
<td>Number of databases searched</td>
<td>.0185</td>
</tr>
<tr>
<td></td>
<td>Use of Boolean operators</td>
<td>.004</td>
</tr>
</tbody>
</table>

Of the remaining variables, mean scores for the experimental group were higher than those for the control group in general on Number of Databases, Number of Synonyms, Number of Correct Search Strategies, and overall Search Success (Topics 1 and 2).
As expected, the level of difficulty of the search topic appeared to have an influence on search outcomes. Topic 2 (the most straightforward) produced overall the most homogenous search strategies for all participants combined: counts for Number of Inappropriate Concepts; Number of Synonyms; Number of Irrelevant Databases; Total Databases; and Number of Reformulations. were the lowest out of the three search topics. The Number of Relevant Databases, however, was the highest. Further, differences between experimental and control groups on variables determined by frequency were the smallest of the three search topics for Number of Concepts; Number of Inappropriate Concepts; Number of Synonyms; Number of Irrelevant Databases; and Number of Reformulations.

Topic 1 was difficult in that the stipulated four relevant articles for a particular year could not be located using a single database; this was reflected in this topic's highest Number of Reformulations out of the three topics.

Topic 3 was the most difficult in terms of locating credible sources, and both treatment groups over-rated their success on this topic.

Of the twelve variables examined, Number of Concepts (appropriate or inappropriate) is the only one that shows a significant difference between experimental and control groups for all three search topics. However, that variable is an important one - unless correct concepts are identified, an appropriate search cannot be devised.

The variables Use of Truncation (Topic 1), and Use of Boolean Operators (Topic 3) are important, in terms of search recall and precision. Wider concept identification, more frequent use of truncation, and greater sophistication of Boolean operators by the experimental group did not however translate into
significantly better search strategies, and overall Search Success was only slightly better for the experimental treatment for Topics 2 and 3. However, there was also a significant difference in the number of databases searched between treatments for Topic 3 - perhaps this was one of the reasons why the experimental group achieved a greater overall search success. As this topic was the most difficult, this result is encouraging.

The decision was made to reject the null hypothesis, and to conclude that the experimental and control groups were different in terms of search performance on a number of variables.

7.2.3 Research Question 3

The third research question was: are problem-solving ability and information retrieval effectiveness related?

Hypothesis 3 (null form): there is no difference in search performance depending on problem-solving ability.

In order to analyse the results for hypothesis 3, a statistical test known as "cross product ratio analysis" was used on some of the variables. In their research into information retrieval, Saracevic & Kantor (1988:172) discussed the utility of cross ratio analysis, and described it as a “powerful technique widely used in biomedicine.” They found it similarly powerful in explaining factors that affect chances of retrieved items being relevant.

Saracevic & Kantor (1988) argued that cross ratio analysis was a useful statistical test because firstly, the t-score generated a measure of statistical significance of the effect being tested, and secondly, the value of the odds ratio itself provided a simple way of describing the importance, or odds, of a particular variable. As its name implies, the ratio is generated by calculating the ratio of two cross products. Cross product ratio analysis was also used by
Collantes (1995) to explore the relationship between naming items and retrieval success.

Saracevic & Kantor (1988) observed that a limitation of the method is that it can be performed when variables are divided into two classes only. Cross ratio analysis yields a $t$-score (the measured value of the log odds ratio divided by its standard deviation) which, if $>2$, indicates significance (even if $t$ is negative). For example, results would indicate that if a searcher scored above the mean (the "cut point" above which a value is high, and below which a value is low) on Survey 1, Section 3 (problem solving), they were more likely to use more concepts in their search strategy formulations than if they had a low value for problem solving.

In the present study, the researcher has used cross ratio analysis to generate odds that, for example, a given variable such as a problem-solving score above the mean, will result in the use of more concepts, and to determine relationships (if any) between problem-solving ability and: Suitable Search Strategies; Use of Truncation; Use of Boolean Operators; Self-Evaluation of Search Success; and Overall Search Success.

Results are summarised in Table 7-39 below.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Topic 1</td>
</tr>
<tr>
<td>Suitable Search Strategy</td>
<td>.877</td>
</tr>
<tr>
<td>Use of Truncation</td>
<td>1.28</td>
</tr>
<tr>
<td>Use of Boolean Operators</td>
<td>.88</td>
</tr>
<tr>
<td>Self-Evaluation of Search Success</td>
<td>1.18</td>
</tr>
<tr>
<td>Search Success</td>
<td>.54</td>
</tr>
</tbody>
</table>
Participants who scored above the mean (5.71) on problem solving were more likely, on Topic 1, to use any sort of truncation (28%); and to self-rate their search success as "useful" or "very useful" (18%).

For Topic 2, subjects scoring above the mean on problem solving were 71% more likely to use truncation, and 3.5 times more likely to use Boolean "AND/OR" operators, than those scoring below the mean.

For Topic 3, subjects scoring above the mean on problem solving were 28% more likely to use Suitable Search Strategies, 8% more likely to use truncation, and 4% more likely to rate their searches as successful, than subject who scored below the mean on problem solving.

Further, log cross ratio analysis suggested that participants who scored above the mean on problem-solving questions (Survey 1, Section 3), were 90% more likely to score above the mean on electronic database knowledge questions (Survey 1, Section 2), than participants who scored below the mean on problem solving; see Table 7-40.
Table 7-40: Log Cross Ratio Calculation: Problem-solving Ability and Electronic Database Knowledge

<table>
<thead>
<tr>
<th>Electronic database knowledge (mean = 10.7)</th>
<th>Problem-solving ability (mean = 5.71)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below mean</td>
</tr>
<tr>
<td>Below mean</td>
<td>57</td>
</tr>
<tr>
<td>Above mean</td>
<td>47</td>
</tr>
<tr>
<td>Total</td>
<td>104</td>
</tr>
</tbody>
</table>

Above mean odds: $= \frac{92}{59} = 1.56:1$

Below mean odds: $= \frac{47}{57} = .82:1$

Ratio: $= \frac{1.56}{.82} = 1.90 = 90\%$

Number of Concepts, Number of Reformulations, Number of Synonyms and Number of Databases were correlated with problem-solving scores. Results indicated that there were significant correlations between problem-solving ability and Number of Synonyms (Pearson’s $r = .2153; p = .026$); Number of Reformulations (Spearman’s $r = .1872; p = .046$); and Number of Concepts (Pearson’s $r = .2132; p = .020$) on Topic 2.

On Topic 3, there was a significant correlation between problem-solving score and Number of Concepts (Pearson’s $r = .2071; p = .027$), and Number of Reformulations (Pearson’s $r = .2320; p = .028$).

There were no significant correlations between problem-solving score and these variables for Topic 1.
T-tests for mean differences between subjects who scored above or below the mean on problem solving, and the seven variables determined by frequency for each of the three search topics indicated that, although the differences were not significant, problem solvers above the mean identified more concepts on all three search topics, and identified more synonyms, and used more reformulations than those below the mean, on Topics 2 and 3. Finally, they accessed more relevant databases on Topic 2, and more databases in total on Topic 3.

The decision was made to reject the null hypothesis; and to conclude that there does appear to be a difference in search performance depending on problem-solving ability.

In terms of the two-stage model of the information retrieval process, naturally good problem solvers, as measured on the pre-test, performed better on stage 1, on two of the three search topics. At the second stage of the model, they performed better at search mechanics: use of truncation (Topics 1 and 2) and complex Boolean operators, Synonyms and Reformulation on one or more search topics. Moreover, their metacognitive skills - the ability to evaluate search success - was better on Topic 1.

It appears that subjects scoring above the mean on problem solving (independent of treatment group) were more likely to use the tools that make searching more effective: truncation, which improves recall; and complex Boolean operators, which improve precision.

When compared to the results from Research Question 2, these findings regarding problem solving are very interesting. To enable comparisons to be made, Table 7-41 summarises the mean scores, as a function of treatment, for
variables determined by frequency. Table 7-42 summarises mean scores, as a function of problem-solving ability, for the same variables.

In Table 7-41, experimental group means that are higher than control group means appear in bold type. Significant p-values are also in bold. Table 7-41 indicates that experimental group means were higher than control group means on 16 of the 21 variables measured. Four of these values were significant. Three of the significant differences were in relation to concept identification (that is, the first stage of the proposed two-stage information retrieval model). The experimental group means were higher than the control group means on all seven variables determined by frequency for Topic 3, the most difficult search topic.
<table>
<thead>
<tr>
<th>Topic 1</th>
<th>Experimental Mean</th>
<th>Control Mean</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Concepts</td>
<td>3.15</td>
<td>2.74</td>
<td>.039</td>
</tr>
<tr>
<td>Number of Inappropriate Concepts</td>
<td>0.41</td>
<td>0.30</td>
<td>.211</td>
</tr>
<tr>
<td>Number of Relevant Databases</td>
<td>1.90</td>
<td>1.93</td>
<td>.856</td>
</tr>
<tr>
<td>Number of Irrelevant Databases</td>
<td>1.03</td>
<td>0.86</td>
<td>.762</td>
</tr>
<tr>
<td>Total Number of Databases</td>
<td>3.01</td>
<td>3.49</td>
<td>.409</td>
</tr>
<tr>
<td>Number of Synonyms</td>
<td>0.58</td>
<td>0.44</td>
<td>.317</td>
</tr>
<tr>
<td>Number of Reformulations</td>
<td>5.00</td>
<td>4.50</td>
<td>.502</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic 2</th>
<th>Experimental Mean</th>
<th>Control Mean</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Concepts</td>
<td>2.80</td>
<td>2.47</td>
<td>.000</td>
</tr>
<tr>
<td>Number of Inappropriate Concepts</td>
<td>0.22</td>
<td>0.17</td>
<td>.345</td>
</tr>
<tr>
<td>Number of Relevant Databases</td>
<td>2.23</td>
<td>2.43</td>
<td>.522</td>
</tr>
<tr>
<td>Number of Irrelevant Databases</td>
<td>0.90</td>
<td>0.86</td>
<td>.944</td>
</tr>
<tr>
<td>Total Number of Databases</td>
<td>3.35</td>
<td>3.51</td>
<td>.705</td>
</tr>
<tr>
<td>Number of Synonyms</td>
<td>0.52</td>
<td>0.34</td>
<td>.133</td>
</tr>
<tr>
<td>Number of Reformulations</td>
<td>3.68</td>
<td>3.81</td>
<td>.825</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic 3</th>
<th>Experimental Mean</th>
<th>Control Mean</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Concepts</td>
<td>2.30</td>
<td>2.28</td>
<td>.903</td>
</tr>
<tr>
<td>Number of Inappropriate Concepts</td>
<td>0.69</td>
<td>0.50</td>
<td>.033</td>
</tr>
<tr>
<td>Number of Relevant Databases</td>
<td>2.04</td>
<td>1.58</td>
<td>.290</td>
</tr>
<tr>
<td>Number of Irrelevant Databases</td>
<td>1.87</td>
<td>1.69</td>
<td>.680</td>
</tr>
<tr>
<td>Total Number of Databases</td>
<td>4.20</td>
<td>2.89</td>
<td>.015</td>
</tr>
<tr>
<td>Number of Synonyms</td>
<td>0.87</td>
<td>0.60</td>
<td>.129</td>
</tr>
<tr>
<td>Number of Reformulations</td>
<td>4.56</td>
<td>4.05</td>
<td>.477</td>
</tr>
</tbody>
</table>
In Table 7-42, variables on which subjects greater than or equal to the mean problem-solving score performed better than those below the mean, appear in bold type. Table 7-42 indicates that subjects who scored above the mean on the problem-solving instrument performed better than subjects who scored below the mean, on 12 of the 21 variables determined by frequency, although none of the differences was significant. For Topic 3, this trend held for six of the seven variables.

This result lends weight to the proposition that problem solving is involved with information retrieval effectiveness, as it would be expected that problem-solving ability would make a difference on the most difficult search task. Although these mean differences were not significant, the trend in higher means was sustained in all search topics, as was the case with the performance of the experimental treatment group.
Table 7-42: Variables Determined by Frequency: Problem Solving Above and Below Mean on Pre-test

<table>
<thead>
<tr>
<th>Topic</th>
<th>Problem Solving Above Mean (&gt;=5.71)</th>
<th>Problem Solving Below Mean (&lt;5.71)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Concepts</td>
<td>3.01</td>
<td>2.75</td>
<td>.201</td>
</tr>
<tr>
<td>Number of Inappropriate Concepts</td>
<td>0.38</td>
<td>0.29</td>
<td>.298</td>
</tr>
<tr>
<td>Number of Relevant Databases</td>
<td>1.89</td>
<td>1.96</td>
<td>.733</td>
</tr>
<tr>
<td>Number of Irrelevant Databases</td>
<td>0.61</td>
<td>1.39</td>
<td>.255</td>
</tr>
<tr>
<td>Total Number of Databases</td>
<td>3.11</td>
<td>3.53</td>
<td>.470</td>
</tr>
<tr>
<td>Number of Synonyms</td>
<td>0.47</td>
<td>0.55</td>
<td>.569</td>
</tr>
<tr>
<td>Number of Reformulations</td>
<td>4.60</td>
<td>4.94</td>
<td>.639</td>
</tr>
<tr>
<td>Topic 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Concepts</td>
<td>2.67</td>
<td>2.55</td>
<td>.200</td>
</tr>
<tr>
<td>Number of Inappropriate Concepts</td>
<td>0.17</td>
<td>0.22</td>
<td>.427</td>
</tr>
<tr>
<td>Number of Relevant Databases</td>
<td>2.44</td>
<td>2.18</td>
<td>.407</td>
</tr>
<tr>
<td>Number of Irrelevant Databases</td>
<td>0.56</td>
<td>1.40</td>
<td>.248</td>
</tr>
<tr>
<td>Total Number of Databases</td>
<td>3.31</td>
<td>3.64</td>
<td>.444</td>
</tr>
<tr>
<td>Number of Synonyms</td>
<td>0.48</td>
<td>0.34</td>
<td>.221</td>
</tr>
<tr>
<td>Number of Reformulations</td>
<td>3.89</td>
<td>3.54</td>
<td>.557</td>
</tr>
<tr>
<td>Topic 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Concepts</td>
<td>2.34</td>
<td>2.21</td>
<td>.227</td>
</tr>
<tr>
<td>Number of Inappropriate Concepts</td>
<td>0.61</td>
<td>0.53</td>
<td>.361</td>
</tr>
<tr>
<td>Number of Relevant Databases</td>
<td>1.69</td>
<td>1.90</td>
<td>.632</td>
</tr>
<tr>
<td>Number of Irrelevant Databases</td>
<td>1.97</td>
<td>1.43</td>
<td>.219</td>
</tr>
<tr>
<td>Total Number of Databases</td>
<td>3.77</td>
<td>3.00</td>
<td>.145</td>
</tr>
<tr>
<td>Number of Synonyms</td>
<td>0.72</td>
<td>0.71</td>
<td>.987</td>
</tr>
<tr>
<td>Number of Reformulations</td>
<td>4.32</td>
<td>4.21</td>
<td>.876</td>
</tr>
</tbody>
</table>
Further, when results for all variables measured are compared for treatment groups and for problem solving, further support is suggested. Table 7-43 summarises the variables on which the experimental treatment group, and better problem solvers, performed significantly better than did control group subjects, or less effective problem solvers.

Table 7-43: Summary of Differences on Variables Measuring Information Retrieval Effectiveness as a Function of Treatment, and of Problem-Solving Score

<table>
<thead>
<tr>
<th>Variable</th>
<th>Topic 1</th>
<th>Topic 2</th>
<th>Topic 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Concepts</td>
<td>Experimental</td>
<td>Experimental</td>
<td>Problem solving</td>
</tr>
<tr>
<td>Number of Inappropriate Concepts</td>
<td></td>
<td></td>
<td>Experimental</td>
</tr>
<tr>
<td>Number of Synonyms</td>
<td></td>
<td>Problem solving</td>
<td></td>
</tr>
<tr>
<td>Use of Truncation</td>
<td>Experimental</td>
<td>Problem solving</td>
<td>Problem solving</td>
</tr>
<tr>
<td>Use of Boolean and/or Operators</td>
<td>Problem solving</td>
<td>Experimental</td>
<td></td>
</tr>
<tr>
<td>Number of Reformulations</td>
<td>Problem solving</td>
<td>Problem solving</td>
<td>Problem solving</td>
</tr>
<tr>
<td>Number of Databases</td>
<td></td>
<td></td>
<td>Experimental</td>
</tr>
<tr>
<td>Suitable Search Strategy</td>
<td></td>
<td></td>
<td>Problem solving</td>
</tr>
<tr>
<td>Self-evaluation of Search Success</td>
<td>Experimental Problem solving</td>
<td>Problem solving</td>
<td></td>
</tr>
</tbody>
</table>

Note: Italics denote values determined by cross ratio analysis of odds of good problem solvers performing better than poor problem solvers. All other values are statistically significant.
Good problem solvers, and the experimental treatment group, were strong overall on concept identification. Both of these groups also performed well on search mechanics (Truncation, Boolean Operators) on at least one topic. Interestingly, both groups rated their search success on Topic 1 quite highly.

It might therefore be concluded that the Module helped participants to develop search techniques that were used by naturally good problem solvers.

7.3 Other Correlates

7.3.1 Research Question 4

The fourth research question asked: are problem-solving ability and cognitive maturity related?

Hypothesis 4 (null form): there is no relationship between problem-solving ability and cognitive maturity.

In terms of Piaget's (1952, in Mellon & Sass, 1981) cognitive developmental levels, students who are able to reason, to think hypothetically, and to understand concepts, are in the category of "formal operations". Perry's (1968, 1981, in King & Kitchener, 1994) developmental level that corresponds to this is "complexity". Students who believe that situations are "black and white", and are ready to make assumptions on insufficient evidence, are described as "dualistic" thinkers by Perry (known in Piaget's terms as "concrete operations"). According to these theories, the level of thinking at which abstract concepts can be understood and manipulated is not achieved by all students, yet the desirability of graduates' possessing such advanced level, or "higher order", thinking skills is unarguable.
The answers given by participants to Survey 1, Section 4 relating to thinking maturity, as discussed in Chapter 3 of this thesis, are set out in Table 7-44 below. The researcher notes that as this section of the Survey was limited in its scope due to time constraints for administering of the Survey, and as some subjects did not have time to finish this section, results are exploratory only.

Table 7-44: Complex and Dualistic Answers to Survey 1, Section 4: Questions 1, 2 and 3

<table>
<thead>
<tr>
<th>Qn 1</th>
<th>Qn 2</th>
<th>Qn 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>%</td>
<td>Count</td>
</tr>
<tr>
<td>Complex</td>
<td>203</td>
<td>91.0</td>
</tr>
<tr>
<td>Dualistic</td>
<td>14</td>
<td>6.3</td>
</tr>
<tr>
<td>Neither complex nor dualistic</td>
<td>6</td>
<td>2.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>223</td>
<td>100</td>
</tr>
</tbody>
</table>

Question 1 of Survey 1, Section 4 described a scenario in which a tutor replies to a student’s question, “I can’t answer that question. Sometimes x is right, and sometimes y is right. It depends”. Six per cent of participants (14 participants) thought that such an answer meant that the tutor did not know the correct answer.

Question 2 required participants to make a judgment about the correctness or otherwise of an employee being dismissed, given a set of circumstances. Nearly 15% of participants (n = 32) selected the “dualistic” answer - that the employee had been dismissed appropriately - even though there was not enough information in the question to make an informed judgment.

Question 3 described a scenario in which a lecturer is explaining several theories to a class. Participants were requested to indicate whether or not they would expect the lecturer to tell them which theory was right. Seven per
cent (n = 15) of the participants thought that the lecturer should tell the class which was the "right" theory.

Results in Table 7-44 above suggest that for each question, a small percentage of participants were thinking at a "dualistic" level.

Table 7-45 below summarises the total number of "complex" or "dualistic" answers given by each participant for Survey 1, Section 4.

Table 7-45: Total Number of "Complex" and "Dualistic" Answers for Survey 1, Section 4

<table>
<thead>
<tr>
<th>Number of Answers</th>
<th>Total &quot;Complex&quot; Qns</th>
<th>Total &quot;Dualistic&quot; Qns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>%</td>
</tr>
<tr>
<td>0 (neither complex nor dualistic)</td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>9.0</td>
</tr>
<tr>
<td>2</td>
<td>70</td>
<td>31.4</td>
</tr>
<tr>
<td>3</td>
<td>130</td>
<td>58.3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>223</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Results suggested that 20.6% of subjects gave at least one "dualistic" response.

In order to determine whether "complex" and "dualistic" thinkers were evenly distributed between experimental and control groups, a Mann-Whitney U test was performed. Results indicated no statistically significant difference between the groups on either "complex" answers (p = .9212), or "dualistic" answers (p = .2730).
A one-way analysis of variance was performed in order to determine whether the score on Survey 1, Section 4 (thinking maturity), affected the mean on Survey 1, Section 3 (problem solving). Results suggested a significant difference on problem-solving mean score between subjects who gave three "complex" answers on Survey 1, Section 4, and subjects who gave no "complex" answers (p = 0.000). Pearson's correlation for the two sections was also significant, and positive (r = .3300; p = .000). In other words, the higher the number of "complex" answers, the higher the problem-solving score tended to be.

Further, only 58% of participants selected the "complex" answer on all three questions. Twenty three per cent of participants gave between 1 and 3 "dualistic" answers. It may be possible therefore, that a significant minority of first-year undergraduates are not yet "complex" thinkers who are able to understand concepts and hypothetical scenarios.

A t-test for relationship between Age and score on cognitive maturity was also conducted; results suggested that there was a significantly higher number of complex answers for subjects aged 41-50 years, than those under 20 years (p = .006). Further, when the number of "complex" answers was compared with performance on the three most difficult problem-solving questions (questions 9, 4 and 7) a significant positive correlation was found (p = .043).

The decision was made to reject the null hypothesis, and to conclude that, although the results are tentative, there may be a relationship between cognitive maturity and problem solving.

Further research is needed on this topic before any less tentative conclusions can be drawn.
7.3.2 Research Question 5

Research question 5 asked "Are there any differences in the search behaviour of more effective and less effective searchers?"

Hypothesis 5 (null form): good searchers do not identify more concepts, do not use a greater number of relevant databases, and do not use better search strategies, than do poor searchers.

In order to test this hypothesis, data for the variable Overall Search Success for each search topic was recoded so that two groups were created: group 1, the "poor searcher" group, contained those subjects who were rated "inadequate" or "marginally adequate" on Overall Search Success. Group 2, the "good searcher" group, contained those subjects who were rated "adequate", "good" or "superior" on Overall Search Success for each search topic.

T-tests were performed to compare these two groups on the variables "Number of Concepts" and "Number of Relevant Databases" for each topic. No significant differences on these variables were found between the "poor" searchers and the "good" searchers. That is, "good" searchers did not appear to vary significantly from "poor" searchers on the number of concepts they used, or on the number of relevant databases they searched.

However, a chi-square analysis of differences between "good" and "poor" searchers on their use of effective search strategies, that is, the way concepts were combined, for each topic revealed significant differences on Topic 2 and Topic 3 (Topic 2: \( p = 0.014 \); Topic 3: \( p = 0.049 \)).

The decision was made to reject the null hypothesis, and to conclude that although "good" and "poor" searchers as evaluated by their performance on the Information Retrieval Assignment did not vary significantly the variables
Number of Concepts, or Number of Appropriate Databases, the Overall Search Strategies they employed were significantly different, resulting in a higher rate of search success for the “good” category of searchers.

It may be that the use by more successful searchers of better search strategies was the result of their superior pattern recognition skills; that is, they may have been able to form a more accurate representation of the problem, and so construct more successful search strategies to meet the perceived information need. This issue of superior pattern recognition skills in more effective searchers is also given some support when analysing the correlate Number of Reformulations, as a function of the variable prior Use of Electronic Databases.

On all three search topics, subjects whose self-reported use of electronic databases as “Never”, used more reformulations in their searches than did subjects who used electronic databases “Regularly”. Table 7-46 below summarises these data.

Table 7-46: Electronic Database Use and Number of Reformulations for Each Search Topic

<table>
<thead>
<tr>
<th>Electronic Database Use</th>
<th>Topic 1</th>
<th>Topic 2</th>
<th>Topic 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
</tr>
<tr>
<td>Never</td>
<td>17</td>
<td>4.65</td>
<td>20</td>
</tr>
<tr>
<td>Regularly</td>
<td>12</td>
<td>4.36</td>
<td>16</td>
</tr>
</tbody>
</table>

It may be that the greater experience of the “regular” users of electronic databases enables them to become more efficient in recognising which search strategies work, and which do not. This finding is compatible with the literature on expert searching, to the effect that experts are able to perceive...
meaningful patterns, where novices do not (Leshgold et al, 1988 in Marchionini, Dwiggins, Katz & Xia, 1993).

7.3.3 Electronic Database Knowledge and Other Intervening Variables

Age, Gender, Faculty, Computer Anxiety and Computer Ability, Completion of Library Tours, Prior Use of Electronic Databases, and Highest Academic Qualification were all possible intervening variables in this study. Correlates are discussed below.

Age, Computer Enjoyment and Computer Ability

There was a weak negative correlation ($r = -0.1235; p = .000$) between Age and Computer Enjoyment. That is, as Age increased, self-rated enjoyment of computer use decreased.

Further, Computer Ability increased as a function of Computer Enjoyment ($r = 0.4778; p = .000$). The higher subjects evaluated their computer enjoyment, the higher they rated their ability.

Gender and Computer Ability

Female subjects appeared to be more confident with using computers; 15% rated themselves as "poor", compared with 21.3% of males; 36.5% of females rated themselves as "good", compared with 27.5% of males. This result was somewhat unexpected, as information technology is generally regarded as a male-dominated area.

Age and Electronic Database Knowledge

An analysis of variance indicated that participants aged between 31-40 ($n = 28; 11\% \text{ of sample}$) performed significantly better on Survey 1, Section 2 (Electronic Database Knowledge) than other Age categories ($p = .0472$). However, approximately half (13) of the 28 subjects in that age category had completed a University of Canberra Library Tour, compared with
approximately one third of subjects aged 30 years and under, and more subjects in that age category had used electronic databases "sometimes" or "regularly" than had younger subjects.

Age and Status (Full time/Part time)
Seventy three per cent of full time subjects were aged 22 years and under; 85% of part time subjects were aged 23 and over. These data simply confirm the attendance patterns of university undergraduates, to the effect that full-time study is in general undertaken by younger students, and part-time study by mature students. Such patterns of attendance usually reflect family and work factors prevailing at different ages.

Gender, Frequency of Use of Electronic Databases, and Electronic Database Knowledge
Figure 7-5 indicates the relationship between Gender of participant, their Use (self-reported) of Electronic Databases, and their performance on Survey 1, Section 2 - Electronic Database Knowledge.
Figure 7-5: Boxplot Showing Relationship Between Gender, Frequency of Use of Electronic Databases, and Electronic Database Knowledge (Survey 1)

The boxplot shows that the median (represented by a dark horizontal line) score on Electronic Database Knowledge for females was always greater than or equal to the median score for males on Electronic Database Knowledge, regardless of the frequency of Use of Electronic Databases.

The same relationship between Gender, Use of Electronic Databases, and Electronic Database Knowledge was observed on post-test 1 (Survey 2, Section 2).

This difference was not observed between males and females on the problem-solving questions, however.
Gender and Self-Evaluation of Search Success

No significant differences were found between males and females on Self-evaluation of Search Success.

Electronic Database Knowledge and Canberra University Library Tours

An independent samples t-test indicated that there was a significant difference in Electronic Database Knowledge between those participants who had completed a University of Canberra Library Tour (mean on Survey 1, Section 2 = 11.3611), and those who had not (mean = 10.4396; p = .011).

Subjects who had completed Library Tours were equally distributed between treatment groups (27% of the experimental group had completed Library Tours; 29% of the control group had completed Library Tours).

Search Success

No significant difference was found in Search Success between those subjects who had completed University of Canberra Library Tours, and those who had not.

Prior Use of Electronic Databases and Search Success

There was no difference in Search Success between those subjects who had previously used Electronic Databases, and those who had not.

Electronic Database Use, and Knowledge of Electronic Databases

Pearson’s correlation coefficient indicated a significant, weak, positive correlation between Use of Electronic Databases, and Electronic Database Knowledge as measured in Survey 1, Section 2 (r = .2453; p = .000).

Electronic Database Knowledge

An analysis of variance indicated significant results for an effect on mean Electronic Database Knowledge score as a function of: completion of
University of Canberra Library Tour (p = .013); and prior Use of Electronic Databases (p = .015).

7.3.4 Problem Solving and Intervening Variables

Differences in performance on problem-solving questions as a function of Age, Gender, Highest Academic Qualification or Faculty of Study, were investigated using data from Survey 1 (Section 3), and Survey 2 (Section 3).

Results are summarised in Table 7-47 below. Independent samples t-tests revealed significant differences on the correlate of Highest Academic Qualification for both Survey 1 questions, and Survey 1 and 2 questions combined. For Survey 1 (nine questions) subjects performed significantly better if they had a Year 12 qualification, than subjects who held an Undergraduate degree (p = .022). It may be that sample size accounts for this surprising result; there were only 10 subjects with an undergraduate degree, and 188 subjects with a Year 12 or equivalent qualification. Another reason might be that those subjects with a Year 12 qualification might have had more recent experience with problem-solving questions, as they had completed secondary studies only a few months previously. There was no significant difference between these two cohorts when Survey 2 results were included in the analysis.

Subjects who held a Year 12 qualification performed significantly better than subjects who held a TAFE qualification on Survey 1 (p = .005). A one-way analysis of variance to determine whether Highest Academic Qualification (Year 12, TAFE or Undergraduate Degree) affected the problem solving mean showed a significant difference between Year 12 and TAFE subjects (p = .0013).
The significant difference between Year 12 and TAFE qualified subjects was also found when responses for Survey 1 and for Survey 2 were combined (p = .036).

On the correlate Faculty of Study, a one-way analysis of variance showed a significant difference between Applied Science (mean = 5.93), Education (mean = 6.15) and Information Science and Engineering (mean = 4.12; p = 0.21). However, it should be noted that there were only eight subjects from Information Science & Engineering.

There were no significant differences in mean problem-solving score as a function of the other correlates tested: Age and Gender.

Table 7-47 indicates that for the correlate of Age, subjects under the age of 20 performed better than subjects over 20 on problem-solving questions on both surveys, although the difference was not significant. For Gender, there was no difference between groups. TAFE qualified subjects performed least well when both surveys were combined, and second lowest on Survey 1, compared with other sub-categories on the correlate of Highest Academic Qualification.

Subjects from the Faculty of Information Science and Engineering performed least well of the five faculties represented - although the small sample from this Faculty may have influenced the result.

A surprising feature of these results was that regardless of correlate, the mean problem-solving scores were quite low, as the researcher was of the view that with the exception of perhaps three of the 14 questions, the problems were not very difficult. This gap between lecturer perception of difficulty, and actual student ability, is one that should be kept in mind when teaching undergraduate students.
An analysis was conducted to determine whether the ability to answer more or less difficult individual problems varied as a function of the correlates Age, Gender, Highest Academic Qualification and Faculty of Study.

Table 7-47: Summary of Means for Age, Gender, Highest Academic Qualification and Faculty of Study on Problem Solving Questions

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Problem Solving Questions 1 - 9 (Survey 1) ; mean/9</th>
<th>N</th>
<th>Problem Solving Questions 1 - 9 (Survey 1), and 11-15 (Survey 2); mean/14</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 20</td>
<td>108</td>
<td>6.10</td>
<td>69</td>
<td>8.95</td>
</tr>
<tr>
<td>22-22 years</td>
<td>46</td>
<td>5.47</td>
<td>26</td>
<td>8.73</td>
</tr>
<tr>
<td>23-30 years</td>
<td>51</td>
<td>5.54</td>
<td>35</td>
<td>8.74</td>
</tr>
<tr>
<td>31-40 years</td>
<td>28</td>
<td>5.32</td>
<td>17</td>
<td>8.35</td>
</tr>
<tr>
<td>41-50 years</td>
<td>18</td>
<td>5.38</td>
<td>14</td>
<td>7.92</td>
</tr>
<tr>
<td>51 or above</td>
<td>3</td>
<td>4.00</td>
<td>3</td>
<td>6.66</td>
</tr>
<tr>
<td>GENDER</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>167</td>
<td>5.71</td>
<td>109</td>
<td>8.79</td>
</tr>
<tr>
<td>Male</td>
<td>80</td>
<td>5.72</td>
<td>51</td>
<td>8.43</td>
</tr>
<tr>
<td>HIGHEST ACADEMIC QUALIFICATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 12 or equivalent</td>
<td>188</td>
<td>5.93</td>
<td>118</td>
<td>8.93</td>
</tr>
<tr>
<td>TAFE qualification</td>
<td>45</td>
<td>5.08</td>
<td>33</td>
<td>7.93</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>10</td>
<td>4.70</td>
<td>6</td>
<td>8.33</td>
</tr>
<tr>
<td>Higher degree</td>
<td>4</td>
<td>5.50</td>
<td>3</td>
<td>8.33</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>6.00</td>
<td>1</td>
<td>9.00</td>
</tr>
<tr>
<td>FACULTY OF STUDY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Science</td>
<td>29</td>
<td>5.93</td>
<td>20</td>
<td>8.35</td>
</tr>
<tr>
<td>Communication</td>
<td>128</td>
<td>5.67</td>
<td>83</td>
<td>8.73</td>
</tr>
<tr>
<td>Education</td>
<td>39</td>
<td>6.15</td>
<td>23</td>
<td>9.08</td>
</tr>
<tr>
<td>Information Science</td>
<td>8</td>
<td>4.12</td>
<td>5</td>
<td>5.60</td>
</tr>
<tr>
<td>Management</td>
<td>49</td>
<td>5.59</td>
<td>32</td>
<td>8.93</td>
</tr>
</tbody>
</table>
Table 7-48 below shows the percentage of incorrect responses to the nine questions on Survey 1, and for the five questions on Survey 2, for each of the correlates. The questions appear in column one, ranked by the researcher in terms of expected difficulty. This ranking was determined by estimating problem difficulty based on theories identified in the literature review.
Table 7-48: Problem Solving Questions Ranked in Expected Order of Difficulty from Most Difficult to Least Difficult.

| Qun No. | Under 20 n = 107 | 20-22 n = 46 | 23-30 n = 51 | 31-40 n = 28 | 41-50 n = 18 | Female n = 167 | Male n = 79 | Yr 12 n = 187 | TAFE n = 45 | Applied Science n = 29 | Communi
| Qun No. | Under 20 n = 107 | 20-22 n = 46 | 23-30 n = 51 | 31-40 n = 28 | 41-50 n = 18 | Female n = 167 | Male n = 79 | Yr 12 n = 187 | TAFE n = 45 | Applied Science n = 29 | Communi
| Qun No. | Under 20 n = 107 | 20-22 n = 46 | 23-30 n = 51 | 31-40 n = 28 | 41-50 n = 18 | Female n = 167 | Male n = 79 | Yr 12 n = 187 | TAFE n = 45 | Applied Science n = 29 | Communi
| Qun No. | Under 20 n = 107 | 20-22 n = 46 | 23-30 n = 51 | 31-40 n = 28 | 41-50 n = 18 | Female n = 167 | Male n = 79 | Yr 12 n = 187 | TAFE n = 45 | Applied Science n = 29 | Communi
| Qun No. | Under 20 n = 107 | 20-22 n = 46 | 23-30 n = 51 | 31-40 n = 28 | 41-50 n = 18 | Female n = 167 | Male n = 79 | Yr 12 n = 187 | TAFE n = 45 | Applied Science n = 29 | Communi
| Qun No. | Under 20 n = 107 | 20-22 n = 46 | 23-30 n = 51 | 31-40 n = 28 | 41-50 n = 18 | Female n = 167 | Male n = 79 | Yr 12 n = 187 | TAFE n = 45 | Applied Science n = 29 | Communi
| Qun No. | Under 20 n = 107 | 20-22 n = 46 | 23-30 n = 51 | 31-40 n = 28 | 41-50 n = 18 | Female n = 167 | Male n = 79 | Yr 12 n = 187 | TAFE n = 45 | Applied Science n = 29 | Communi
| Qun No. | Under 20 n = 107 | 20-22 n = 46 | 23-30 n = 51 | 31-40 n = 28 | 41-50 n = 18 | Female n = 167 | Male n = 79 | Yr 12 n = 187 | TAFE n = 45 | Applied Science n = 29 | Communi

Chapter 7: Phase 1 - Results
All correlates, and all sub-categories within those correlates, with the exception of those aged 31-40 years, agreed with the researcher's ranking of question 9 as the most difficult to answer, as measured by the percentage of incorrect responses per sub-category. Question 9 required the subject to manipulate several variables, and so to arrive logically at the only correct solution for the given parameters. Although no mathematical knowledge was required, terms such as “volume” and “diameter” were used in the question. Perhaps these terms suggested to students that a quantifiable result could be arrived at, when in fact, the subject had to realise that insufficient information had been given for this to be possible. The correct answer was “it is impossible to know”. Between 57.4% and 79.5% of subjects answered this question incorrectly.

The researcher had expected that subjects would find question 4 the next most difficult question, as again, mathematical terms were used in the question, which necessitated control of variables. However, this question was more straightforward than question 9, and indeed, although 23.5% to 50% of subjects answered it incorrectly, subjects found question 7 - solving a problem by analogy - slightly more difficult.

There was a gradual decline in the number of incorrect responses through questions 5, 8, 3, 6 and 2, as anticipated by the researcher. There were occasional exceptions to this trend, however, and they are discussed under separate correlate headings below.

All correlates (Age, Gender, Highest Academic Qualification and Faculty) performed poorly on the first question in the survey, which the researcher had ranked as the easiest. The percentage of incorrect responses on this question ranged from 38.9% for subjects aged 41-50, to 62.2% for TAFE qualified subjects. The question required subjects to read a short scenario in
which a number of facts were presented. They were then asked to indicate which of a number of conclusions could be drawn from those facts. The correct answer was “none of the above”, as all the other alternatives were inferences drawn from the scenario. No conclusions were possible, as insufficient facts were available.

Figure 7-6 illustrates how on the correlate Age, there is a gradual decline in the percentage of incorrect responses from question 9 through to question 2. For Age, there are fluctuations for sub-categories 31-40, and 41-50, perhaps because of their smaller sample sizes. Answers by subjects aged over 41 do appear to have conformed least to the projections of the researcher. That is, on one question they may have done very well in comparison to other age groups, on another question, the worst.

Subjects aged 31-40 and over performed least well on questions 7, 5 and 6. Interestingly, subjects aged 41-50 performed best on two of these - questions 7 and 6. On these data, then, it may be that subjects aged over 40 performed better. Also, on question 1, which most subjects found the second most difficult question, subjects aged 41-50 performed best.
A similar gradual decline in the percentage of incorrect responses from questions 9 through 2 is also apparent in the Gender correlate (Figure 7-7). There is no large difference in performance as a function of Gender, with the exception of a 15 percentage point difference between male and female on question 8. This question required the speed of a motorcyclist travelling between Sydney and Canberra to be determined, relative to a second motorcyclist. Perhaps the content of the question triggered gender differences in perception.
Figure 7-7: Percentage Incorrect Responses by Gender for Questions 1-9 (Survey 1, 1997)

Figure 7-8 below illustrates that on the correlate Highest Academic Qualification, subjects with a Year 12 qualification performed consistently better than either TAFE qualified subjects, or subjects with an undergraduate degree. The researcher notes however that there were only ten subjects with an Undergraduate degree, while there were 187 with a Year 12 qualification (as might be expected in a first year undergraduate subject).

The better performance of Year 12 subjects, compared with that of TAFE subjects, was most apparent on questions 8 and 9, both of which were logic questions; although Year 12 subjects performed consistently equal to or better than TAFE subjects.

Those subjects with an undergraduate degree performed much worse than other sub-categories on questions 6 and 7; question required inductive reasoning, and question 7, reasoning by analogy.
With regard to Faculty of Study, Communication subjects had the highest percentage of incorrect responses on questions 4, 7, 5, 3, 6 and 2.

These results for performance on each problem-solving question suggest that even though overall mean scores on the survey show little difference between correlates, when problems are classified by degree of difficulty, differences between correlates become evident.

Table 7-49 below provides a ranking of performance on each question, as a function of correlate sub-category. Each time a sub-category obtained the lowest number of incorrect scores for a question, it was given a ranking of one. At the bottom of the Table, a total for each sub-category has been
calculated. For example, at the bottom of the column headed "41-50", it can be seen that this Age sub-category obtained the highest number (four) first rankings for the problem-solving questions. That is, subjects aged between 41 and 50 years performed better than the other Age sub-categories on four of a possible nine problems.

Year 12 subjects performed better than the other two Highest Academic Qualification sub-categories on six of the nine problems. For Gender, performance was almost equal. For Faculty of Study, Management appears to have performed least well.

Table 7-49: Sub-category First Rankings on Problem-Solving Questions

<table>
<thead>
<tr>
<th>Qun No</th>
<th>Under 20 n = 107</th>
<th>20-22 n = 46</th>
<th>23-30 n = 51</th>
<th>31-40 n = 28</th>
<th>41-50 n = 18</th>
<th>Female n = 167</th>
<th>Male n = 79</th>
<th>Yr 12 n = 187</th>
<th>TAFE n = 45</th>
<th>UG n = 10</th>
<th>App Science n = 29</th>
<th>Comm n = 128</th>
<th>Edcn n = 39</th>
<th>Mgt n = 49</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>4</td>
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<td>1</td>
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<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>6</td>
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<tr>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total first rank</td>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Using this ranking system, it would appear that the best predictor of problem-solving ability is Highest Academic Qualification - Year 12; followed by Age - 41-50 Years.
Of the five sub-categories in the correlate of Age, subjects aged 41 and over gained two out of a possible three first rankings on the most difficult questions (9, 4 and 7).

Survey 2 – Ability to Manipulate Hypotheses
The lower section of Table 7-48 shows the percentage of incorrect responses for the questions in Survey 2 regarding the ability to manipulate hypotheses. The questions were ranked in order of difficulty by the researcher. Question 15 was the most difficult, requiring subjects to decide whether new information meant that a conclusion from a previous experiment was supported or not.

Using the same ranking system as that used for the nine problem-solving questions in Survey 1, on Survey 2 - the hypothetical questions - Age sub-categories 20-22 and 23-30 gained two first rankings each, and a tied first ranking between them. No other Age sub-category gained a first ranking on the hypothetical questions.

For Gender, females gained first ranking on four of the five hypothetical questions.

On the correlate of Highest Academic Qualification. Year 12 ranked better than TAFE on three of the five questions. On the correlate of Faculty of Study, the sub-category of Applied Science performed somewhat less well, particularly on the more complex hypotheticals, than did Communication, Management or Education - see Figure 7-9 below.
Figure 7-9: Percentage of Incorrect Responses by Faculty on Survey 2, 1997

For these hypothetical questions, then, the trends in performance observed on Survey 1 held with regard to the correlates of Highest Academic Qualification, and Faculty of Study, but not for Age or Gender. Interestingly, with regard to manipulation of variables, females also performed better than males on question 6, Survey 1 - control of variables. It may be, as suggested in some literature, that females are able to think in abstract terms more easily than males; females in general performed better on questions requiring manipulation of language, compared with males, who performed better on questions involving such elements as mathematics and Venn diagrams.

7.4 Summary of Results

Research Questions and Hypotheses, with their corresponding decisions, are summarised in Table 7-50 below.
### Table 7-50: Phase 1 - Summary of Results

<table>
<thead>
<tr>
<th>No.</th>
<th>Hypotheses (Null Form)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>There is no difference between experimental and control groups on electronic database knowledge in the pre-test</td>
<td>Accept</td>
</tr>
<tr>
<td>1b</td>
<td>There is no difference between experimental and control groups on electronic database knowledge in post-test 1</td>
<td>Reject</td>
</tr>
<tr>
<td>2</td>
<td>There is no difference between experimental and control groups on search performance</td>
<td>Reject</td>
</tr>
<tr>
<td>3</td>
<td>There is no difference in search performance depending on problem-solving ability</td>
<td>Reject</td>
</tr>
<tr>
<td>4</td>
<td>There is no relationship between problem-solving ability and cognitive maturity</td>
<td>Reject</td>
</tr>
<tr>
<td>5</td>
<td>Good searchers do not identify more concepts, use a greater number of relevant databases, and construct more effective search strategies, than do poor searchers.</td>
<td>Reject</td>
</tr>
</tbody>
</table>

In the next chapter, these results are discussed, and conclusions drawn. Areas for further investigation are identified, and an introduction to Phase 2 provided.
8. PHASE 1 - DISCUSSION

A review of the theoretical framework of the study is provided in section 1 of this chapter. In section 2, results for the three central research questions are discussed, and section 3 provides a discussion of the results for research questions 4 and 5. In both of these sections, results are compared to those of previous research reviewed in Chapters 2, 3 and 4.

Conclusions are drawn in section 4, and areas for further investigation identified. Several of these areas were taken up to form the basis of Phase 2 of this research (reported in Volume II).

8.1 Theoretical Framework - Review

Based on a review of literature pertaining to issues in information retrieval (Chapter 3), and on relevant tenets of cognitive psychology (Chapter 4), the researcher suggested that information retrieval from electronic databases may be represented usefully as a two-stage process (Chapter 5). The first stage of the model involves problem recognition and interpretation, and is based on one of the two types of knowledge representation in human memory postulated by cognitive psychologists: declarative knowledge.

In this first stage of information retrieval - problem interpretation - the electronic database end-user has to search their “mental models”, that is, declarative knowledge, in order to find a conceptual framework through which to make sense of the research question. Whether or not an accurate match is found between the research question and existing conceptual knowledge depends on the end-user’s ability to analyse the research question accurately, and on the end-user’s existing conceptual knowledge. Unless the research question is properly understood, it will not be correctly “matched”.

Once the problem has been "recognised", the second stage of the information retrieval process is "running" the search. Newell & Simon's standard information processing model (1972, in Gagne, Yekovich & Yekovich, 1993) has been adapted by the researcher to represent this process. The steps involved in the actual conduct of the search are procedural in nature; they are sequential, iterative, and, particularly in the case of novice end-users, conscious.

The researcher is of the view that this two-stage model may go some way to addressing the lack of theoretical underpinning for search strategy formulation recognised by Lancaster et al (1994).

Further, the researcher suggests that a number of elements derived from learning theory may be useful in the design of instructional modules to develop end-users' performance at both stages of the information retrieval process: problem identification, and search formulation. Learning theory was chosen as the theoretical basis for the experimental module, as it provides a number of teaching techniques that emphasise the development of concept-based knowledge, as opposed to skills development alone. Some literature reviewed in Chapter 3 suggested that concept-based instruction, and problem-solving, may assist the development of effective search strategies, but further research was required. An experimental research design has been employed in part to address the need identified in the literature in Chapter 3 for the conduct of a larger number of methodologically rigorous studies in the field of information retrieval. Literature suggests that only 12.5% of 595 studies conducted on bibliographic instruction in the last 20 years have been experimental (Edwards, 1994). In order to enable statistical analysis of results from the current study, a pre-test/post-test experimental design, with random assignment to experimental and control treatments, was used.
In the next section, the results for the research questions posed to investigate these two issues: the efficacy of the two-stage model as a construct; and the utility of concept-based instruction derived from learning theory, are discussed.

8.2 Central Research Questions

8.2.1 Research Question 1

Literature on the efficacy of concept-based instruction, as opposed to skills-based instruction, for information retrieval is not extensive; results are not always consistent (Balaraman, 1991; Oberman, 1991). The first research question was therefore:

*Will type of instruction influence acquisition of knowledge of electronic database searching?*

In the present study, there was no significant difference between experimental and control groups on electronic database knowledge in the pre-test, and there was a significant difference between those groups on the post-test. Intervening variables (age, Gender, Computer Ability and Enjoyment, previous Use of Electronic Databases, completion of Library Tours) were controlled through the use of an experimental research design with a large sample; and *t*-tests were conducted to check that the treatment groups were homogeneous in terms of these variables. For example, data analysis showed that those subjects who had completed a University of Canberra Library tour performed significantly better on the pre-test measuring Electronic Database Knowledge (Survey 1, Section 2), than those subjects who had not completed a tour; but subjects who had completed a tour were evenly divided between experimental and control treatments, and so this variable could be ruled out as an intervening factor in post-test results.
It was concluded that the teaching Module was successful in improving participants' knowledge of terms and techniques associated with electronic database searching.

The experimental Module included content on identification of concepts, use of Boolean operators, use of truncation, and formulating a search strategy. Results suggested that it was successful in addressing a number of problems in end-user searching that have been identified in the literature: firstly, that end-users are ignorant of search techniques, and do not want to take the time to learn (Hunter, 1991); secondly, insufficient identification of concepts (Spink, 1995; Lancaster et al, 1994; Bates, 1986); and finally, incorrect use of truncation, logical errors and failure to use obvious synonyms (Wildemuth, Jacob, Fullington et al, 1991).

However, knowledge of electronic database searching does not necessarily translate into effective search strategies and retrieval. This issue was addressed with the second research question.

8.2.2 Research Question 2

For the second research question: Will type of instruction influence information retrieval effectiveness?, an Information Retrieval Assignment was used to enable the measurement of the effectiveness of the type of instruction in terms of search strategy formulation and search results. Subjects located citations for articles relating to three search topics of varying difficulty. For each search topic, subjects' assignments were rated on 12 variables: Number of Concepts (Appropriate and Inappropriate); Use of Boolean Operators; Use of Truncation; Number of Synonyms; Number of Reformulations; Number of Databases (Relevant/Irrelevant/Total); Effectiveness of Search Strategy; Overall Search Success; and Self-Evaluation of Search Success.
Results suggested that type of instruction made a significant difference to search performance on one or more of the search topics in terms of Number of Concepts, Use of Boolean Operators, Use of Truncation, Number of Databases, Overall Search Success, and Self-Evaluation of Search Success. Table 8-1 below shows these results for each search topic.

Table 8-1: Significant differences between experimental and control groups for each search topic

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1</td>
<td>Number of concepts</td>
</tr>
<tr>
<td></td>
<td>Use of truncation</td>
</tr>
<tr>
<td></td>
<td>Self-evaluation of search success</td>
</tr>
<tr>
<td>Topic 2</td>
<td>Number of concepts</td>
</tr>
<tr>
<td>Topic 3</td>
<td>Number of inappropriate concepts</td>
</tr>
<tr>
<td></td>
<td>Number of databases searched</td>
</tr>
<tr>
<td></td>
<td>Use of Boolean operators</td>
</tr>
</tbody>
</table>

When all search topics were combined, results indicated that there was a significant difference between performance of the experimental group and the control group on three variables: Number of Concepts, Number of Inappropriate Concepts and Number of Synonyms.

These findings were promising, as in the experimental Module, key components of searching that were emphasised and modelled were concept identification, combining concepts to form search strategies, using Boolean operators and truncation.

Other search components, for example, selecting databases and reformulating search strategies, although discussed, were not actually modelled. It may be that the actual modelling of key components was the most effective teaching strategy in the Module.
Of the twelve 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 (Spink, 1995; Lancaster et al, 1994; Bates, 1986; Borgman, 1986; Saracevic, 1971) has suggested that failure to identify appropriate concepts is one of the main reasons for search inadequacy.

It may be 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 & 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 end-users' failure to use truncation and Boolean operators correctly. These were two of the common errors in end-user searching identified by Wildemuth, Jacob, Fullington 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 the difference was 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 finding 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 number of reformulations used, findings revealed a significant
weak positive correlation between the Number of Reformulations, and:
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 that 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 obtain 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
(1986:86). 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, Jacob, Fullington 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. 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, on all three search topics.

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, de Bliek, Friedman & File (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; and that pattern recognition in experts is far better than that of novices, who typically waste time on irrelevant information (Holyoak, in Osherman & Smith, eds, 1990; Glaser, 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, ie, the first stage of the model of the information retrieval process that the researcher has proposed,
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 & 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 on which to conduct the search. It is essential that any instruction in information retrieval clearly explain 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 & 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 (ie, the first stage of the search process), and in selecting appropriate databases (ie, 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 over-rated 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 of citations 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.

Further, the researcher rated the experimental group higher than the control group on Topics 2 and 3 in overall search success, which indicates that overall, participants in the control group over-rated their search success. The phenomenon of the “false positive” in novice end-user searching - that is, end-users being very happy with poor searches - may explain this result (Applegate, 1993; Bates, 1986; Nielsen & Baker, 1987 in Dwyer, Gossen & Martin, 1991; Hancock-Beaulieu, 1990). It would appear from the results for Topic 1, in which experimental group ratings were comparable to researcher ratings, instruction may assist subjects to form a more realistic assessment of their search success. This realistic assessment is an important part of becoming “formal” thinkers, in which metacognitive tasks - self-monitoring of thinking processes and task success - are incorporated.

In summary, results indicated that, on one or more of the search topics, a number of variables: Number of Concepts (Appropriate or Inappropriate); Use of Truncation; Use of Boolean Operators; Number of Databases; and Self-Evaluation of Search Success - varied with type of instruction. The experimental Module, grounded in learning theory and emphasising a concept-based approach to information retrieval, appeared to influence search strategy formulation, search execution, search success, and subject self-perception of search success, supporting findings of two earlier experimental studies. The first of these was by Kohl & Wilson (1986), in which a significant difference between a “cognitive strategies” instruction style and a “traditional” style was found. The second was Zahner’s (1992) study on “research process orientation”, in which the process of the search was emphasised, rather than the information sources generally. Results of that study suggested that this “cognitive strategies” instruction resulted in
significantly better research paper bibliographies, than those of the “traditional approach” treatment group.

In terms of the two-stage model of the information retrieval process proposed by the researcher, the differences between treatment groups support the efficacy of concept-based teaching at both stages. These findings may go some way to tipping the balance of “scanty or ambiguous” empirical evidence of the efficacy of conceptual models discussed by Sein & Bostrom (1989, in Balaraman, 1991:284), and the lack of efficacy of concept-based teaching suggested by Dixon & Gabrys (1991), in favour of their efficacy.

In stage 1 of the model - the “neural network” stage - question interpretation requires accurate identification of concepts. The experimental group performed better than the control group on this variable on all three topics.

Stage 2 - the “information processing” stage - requires the formulation of effective search strategies, which strategies are enhanced by the identification of synonyms, the use of truncation, and the use of complex Boolean operators. There were significant differences between experimental and control groups on these variables on at least one search topic.

These results suggest that, even though concept-based teaching is helpful in assisting end-users at both stages of the proposed information retrieval model, actual search success is still problematic. It is possible that with more experience and practice, actual search success could improve. However, as most end-users tend to remain “permanent novices” due to their intermittent (and assignment-centred) use of databases, the researcher is of the view that actual search outcomes could be enhanced more immediately by the teaching of critical thinking skills, including the ability to evaluate sources for credibility.
Further research, incorporating the teaching of critical thinking, is suggested in the wider area of information literacy.

8.2.3 Research Question 3

Literature suggests a number of human factors that may influence information retrieval effectiveness (Borgman 1986, 1989; Saracevic & Kantor, 1988). Problem-solving ability is one of these, yet there is little empirical evidence to confirm or deny its role in the information retrieval process. Research question 3 was therefore:

*Are problem-solving ability and information retrieval effectiveness related?*

Results suggested that good problem solvers - that is, subjects who scored above the mean Survey 1, Section 3 - were, on some search topics, more likely to use any sort of Truncation, and use Boolean “AND/OR” operators, than subjects who scored below the mean.

Further, there were significant weak positive correlations between problem-solving score and Number of Concepts identified, Number of Synonyms, on two of the three search topics, and Number of Reformulations used. It was found that better problem solvers were 28% more likely to use successful Search Strategies on Topic 3, than subjects who scored below the mean. However, as was the case with the experimental treatment group, these strategies did not always mean better Search Success.

These results support findings by Allen (1992) that logical reasoning had an effect on search mechanics, but did not influence the quality of the actual searches. Allen, however, was not testing the same cognitive factors (problem solving) that were the subject of the current study.
The result in the current study may be explained in part by: inadequate labelling of databases on the search interface to enable the identification of subjects covered in them; the very specific search parameters for Topic 1; and finally, difficulty in finding “empirical” journal articles for Topic 3. In other words, search strategies were appropriate, but there were a number of factors that made actual retrieval difficult.

When taken in conjunction with the results for Research Question 2, these findings were very interesting, as results from Research Question 2 suggested that there was a significant difference between Number of Concepts used, Use of Boolean Operators, and Use of Truncation, for the experimental group, when compared to the control group.

Variables on which good problem solvers and the experimental treatment group performed significantly better than problem solvers who performed below the mean, and the control group, included Number of Concepts, Use of Truncation, and Boolean Operators. The similarities between the experimental treatment group, and subjects who scored above the mean on problem solving in the pre-test, were most apparent on the most difficult search question - Topic 3. On that topic, with one exception in the problem-solving group, good problem solvers and the experimental treatment group outperformed poor problem solvers and the control group on all seven variables determined by frequency, that measured search effectiveness.

Again, this pattern seems to indicate that effective information retrieval and problem-solving skills only start to make a difference in search performance when the question is not straightforward.

From these results, the researcher has concluded firstly, that human factors - in this case, problem-solving ability - do in fact influence search strategy formulation. It may be that it is not the novice status of the end-user per se that
influences the development of effective search strategies, as was found in a study by Penhale & Taylor (1986); rather, it may be the problem-solving ability of the end-user that has a greater influence on successful search strategy development. This finding is important, because problem-solving can be taught.

The second conclusion is that the experimental Module was useful in teaching subjects search techniques employed naturally by effective searchers. This finding supports Zahner’s (1992) observations regarding the efficacy of a conceptual model in teaching information retrieval; and Saracevic’s (1971) observations that human factors are the major influence on information retrieval.

The success of the Module in improving search performance on some variables - and so emulating strategies employed by end-users who were naturally better searchers; that is, good problem solvers - also supports Borgman’s (1989) conclusions that individual differences are not random, and may be able to be controlled through design and training. The current study’s results regarding the efficacy of concept-based teaching also support Sylvia & Kilman’s (1991:46) observations that “CD-ROM information overload can be reduced through the use of conceptually grounded search strategies”.

8.3 Other Correlates

8.3.1 Research Question 4

Literature suggests that cognitive maturity may affect students’ ability to think hypothetically, and to understand and execute problem-solving routines (Marini & Case, 1994). Accordingly, research question 4 was:

*Are problem-solving ability and cognitive maturity related?*
Cognitive maturity was measured on pre-test (Survey 1, Section 4). Only 51% of subjects selected the “complex” answer on all three questions. Nearly 24% of participants gave between 1 and 3 “dualistic” answers. It may be possible therefore, that a significant minority of first-year undergraduates are not yet consistently “complex” thinkers who are able to understand concepts and hypothetical scenarios.

These findings support observations by Oberman (1991) and McNeer (1991) that formal thinking should not be assumed at tertiary level. The findings also support those of Kamii (1984, in Biehler & Snowman, 1993) suggesting that only 20-25% of college freshmen are able to use formal operation reasoning consistently.

Further, the data suggested that the higher the number of “complex” answers a participant gave on Survey 1, the higher their score in problem solving. Although further research is needed on this topic before any less tentative conclusions can be drawn, it does appear that cognitive maturity may affect problem-solving ability.

There are a number of implications for teaching in higher education arising from these findings. Firstly, a significant minority of students may have difficulty thinking in the formal, hypothetical manner that is often expected of them. Secondly, lecturers may assist students unable to think at an appropriately complex level to develop a more realistic and comprehensive understanding of their subject through assisting students to develop more complex schemas of their subject. Techniques include introducing complexity; explaining the significance of context; modelling appropriate thinking and problem-solving behaviours; and discussing exceptions and variations to concepts being taught.
8.3.2 Research Question 5

Information processing theory suggests that pattern recognition in experts is far better than that of novices, who typically waste time on irrelevant information. Pattern recognition refers to the ability of a subject to identify relevant patterns, or relationships, in a given situation. In the information retrieval context, pattern recognition might be suggested by a subject’s search strategy formulation. The number and type of concepts used to characterise the research question; the type of database(s) selected, and the type of search strategies, could all indicate differences between pattern recognition in good searchers, and in poor searchers. In this context, “good” searchers are those who rated “adequate”, “good” or “superior” on the Search Success variable. Research question 5 was therefore:

Are there any differences in the search behaviour of more effective and less effective searchers?

Subjects classified as more effective and less effective searchers were compared on the variables “Number of Concepts” and “Number of Relevant Databases” for each search topic, but “good” searchers did not appear to vary significantly from “poor” searchers on the Number of Concepts they used, or on the Number of Relevant Databases they searched. However, they did differ on their use of effective search strategies for Topics 2 and 3.

The better search strategies employed by more effective searchers may have been the reason why those searchers also achieved a significantly higher rate of search success. It may be that the use by more successful searchers of better search strategies was the result of their superior pattern recognition skills; that is, they may have been able to form a more accurate representation of the problem, and so construct more successful search strategies to meet the perceived information need. This ability was described by Vigil (1988) in the context of information retrieval as “survey knowledge”.

Chapter 8: Phase 1 - Discussion
The Number of Reformulations also appeared to be an indicator of superior pattern recognition; those subjects who used electronic databases "regularly" used fewer reformulations than those subjects who "never" use electronic databases, on all three search topics.

Further research is required into the possible relationships between pattern recognition and novice/expert differences.

8.3.3 Problem Solving Ability of Participants

Problem-solving ability of participants was measured on the pre-test (Survey 1, Section 3) in order to gauge its impact on information retrieval correlates. These issues were discussed in section 8.2.3. Data gathered in this instrument was also very illuminating in terms of the problem-solving abilities of first-year undergraduates generally, and these issues are discussed below.

Four variables that were measured in the pre-test that possibly impact on problem-solving ability were Age, Gender, Highest Academic Qualification and Faculty of Study. Results suggested that Highest Academic Qualification was significantly correlated with mean problem-solving score. Those subjects with a Year 12 qualification \( n = 176 \) performed significantly better than did those subjects with a TAFE (technical college) qualification \( n = 45 \).

This may explain to some extent the relationship found by Dickson, Fleet & Watt (2000) regarding former TAFE students, and failure in university teacher education subjects at an Australian metropolitan university. Further, a study by Macquarie University (MPIU, 1996, cited in Dickson et al, 2000) found that students entering university with a completed degree performed better than the TAFE students, but worse than school leavers (Year 12). The results of the current study provide some support for these findings, in that the subjects
with an undergraduate degree performed worse on problem solving that did Year 12 subjects.

The problems were of the type that it would be expected that subjects with a higher degree of cognitive maturity would perform better than other subjects.

Those subjects studying in the Faculty of Applied Science, and in Education, performed significantly better than did those subjects from the Faculty of Information Sciences & Engineering; although, as there were only eight subjects from that latter faculty, the researcher notes that this result is very tentative, and could be explained in other ways - such as, an unrepresentative sample of Information Science students.

Although no significant relationship was found between Age and problem-solving ability, subjects aged 31 and over performed better than subjects in any other age category on six of the nine problem-solving questions in Survey 1. If problem-solving ability is a factor that affects student performance, then this finding does not support those of Dickson et al (2000), who found no relationship between age and ability overall to complete undergraduate subjects generally.

No differences in problem-solving score were observed as a function of Gender.

A surprising feature of these results to the researcher was that mean problem-solving scores were relatively low, as the researcher was of the view that with the exception of perhaps three questions on the survey, the problems were not very difficult. Lower than anticipated scores were also found when a similar survey on problem solving was administered to third year management students at the same university (Macpherson, 2002). This gap between
lecturer perception of difficulty, and actual student ability, is one that should be kept in mind when teaching undergraduate students.

The nine problems in Survey 1 were ranked by the researcher in order of difficulty from highest difficulty to lowest. Based on theoretical constructs discussed in the literature review, it was expected that question 9 would be the most difficult to answer. This question contained multiple "vectors" (Marini & Case, 1994) that needed to be manipulated in order for a correct answer to be given. Subjects' responses were analysed to determine whether performance on the four variables tested (Age, Gender, Highest Academic Qualification and Faculty of Study), reflected the researcher's rankings. The researcher's rankings were reflected across the variables in general, with the exception of question 1, which had been ranked as the easiest by the researcher, but was fourth most difficult according to the subjects' performance. This question had required subjects to draw a conclusion based on the facts of a short scenario. Most subjects drew inferences from the facts, rather than drawing conclusions based on demonstrable fact alone.

These results indicated that more than half of all participants gave incorrect answers on the three most difficult questions. It is possible to conclude that undergraduate problem-solving ability (whether students are school leavers, TAFE qualified or mature aged) may not be as highly developed as would be expected, particularly on problems requiring reasoning by analogy, determination of relevance, and critical thinking.

With regard to "formal" thinking, as evidenced by the ability to manipulate hypotheses, it would appear that the great majority of subjects was able to judge the validity of conclusions, provided that new information was straightforward. However, once the new information became more complex, many subjects had difficulty determining what effect this information would have on the conclusions drawn from the original experiment.
If this is the case, then in the context of doing research for assignments, for example, many undergraduates might have difficulty determining the relevance of what they read to the question they are trying to answer, which would explain why many undergraduates (particularly in first year), complain that they cannot find useful information for assignments.

**Implications for Teaching in Higher Education**

There are a number of implications for teaching and learning in higher education arising from the results of this study on problem solving, and on cognitive maturity.

Firstly, the gap between lecturer perception of difficulty, and actual student ability, is one that should be kept in mind when designing curricula for undergraduate students. It should be remembered that something that seems straightforward to the lecturer, as an expert, may be difficult to grasp for the student, as a novice.

Secondly, as so many students seem to have difficulty with critical thinking and problem-solving skills such as determining relevance, reasoning by analogy and causal reasoning, it may be appropriate for first-year lecturers to incorporate modules into their subjects that address the development of these skills.

Results from this study regarding the efficacy of teaching strategies incorporating explicit teaching of problem solving indicate that problem-solving ability may be able to be enhanced in undergraduates.

Thirdly, lecturers cannot assume that all students, particularly in first year, will appreciate the significance of lecture and other teaching material.
presented, as a proportion of students cannot distinguish relevant from irrelevant information, cannot reason effectively by analogy, and may not always possess the cognitive maturity necessary to understand hypothetical scenarios. The experimental Module’s success in terms of improving subjects’ performance on some search variables suggests that teaching why, not just how and what, may be useful, and to develop more complex mental representations of what is being taught.

Fourthly, as it is possible that a significant minority of students in all undergraduate years seems to think at a “dualistic” level, lecturers may assist these students to develop a more realistic and comprehensive understanding of their subject by introducing complexity, by explaining the significance of context, by modelling appropriate thinking and problem-solving behaviours, and by discussing exceptions and variations.

Finally, in today’s information society, there is an expectation that university graduates will be able to apply their learning to the solution of real-world problems. They are exhorted to be creative, and innovative, in this problem-solving role. However, if graduates cannot reason by analogy, they will find it difficult to be creative or innovative, as these factors result frequently from the ability to make connections between one situation and another, ie, reasoning by analogy; and to distinguish between relevant and irrelevant information.

8.3.4 Profile of Australian Undergraduate Students’ Computer Literacy
The demographic data gathered in the pre-test (Survey 1, Section 1) of this study reinforce data gathered by Tapper (1997) regarding the variable level in computer literacy of first year undergraduates in Australia. Tapper conducted a study that measured computer literacy in students at the University of Melbourne. Subjects were 45 undergraduates in a unit that taught basic
computing skills. Sixty two per cent of those subjects were in first year; 60% were female; 76% were studying humanities and social sciences. Tapper concluded that online experiences of entry-level university students in Australia were mixed in her sample, and she called for further investigation into issues involved with online literacy in tertiary education in Australia. Elements of the current study that respond to some of the findings of the Tapper study appear below.

In the Tapper study (n = 37), 70.2% accessed computers at home and at work “often”; and 97.2% accessed computers at home and at university “often”. In the current study, over 74% of participants (n = 249) had access to computers at home, and in at least one other location (work or school). No participants reported having no access to computers.

With regard to attitudes to online literacy, 67.5% of participants in the Tapper study had favourable or highly favourable attitudes to computers. In the current study, 76.6% of participants held similar views.

Further, in the current study, it was found that computer literacy was correlated positively with enjoyment of using computers; age was negatively correlated with computer literacy.

As computer literacy and use are integral to effective participation in today's information society, further research into computer literacy in undergraduates would be useful to determine the current situation. Even in 1997, up to 67% of undergraduates surveyed by Tapper, and 76% of those subjects in the current study, had favourable attitudes to computer use. These favourable attitudes however, did not always equate to success in information retrieval tasks in the current study; clearly, other skills are needed to be effective as end-user searchers apart from access to computers, favourable attitudes and a self-reported competence in the use of computers.
It is the researcher's contention that these other skills are those involved with information literacy: a problem-solving heuristic; and critical thinking.

8.4 Conclusions

In Chapter 1, it was suggested that successful database searching is contingent on a combination of technical skills, and information retrieval conceptual knowledge. Further, that teaching strategies grounded in learning theory may be useful to the development of such conceptual knowledge.

A third suggestion was that an effective problem-solving strategy may contribute to the achievement of successful search outcomes.

The researcher suggested that cognitive psychology may be of value to the understanding of the thinking processes underpinning information retrieval; the development of teaching strategies that may facilitate the acquisition of conceptual knowledge of searching; and an explanation as to why individual differences in thinking maturity may influence information retrieval effectiveness.

In order to provide a possible theoretical underpinning for the mechanisms involved in the information retrieval process, a two-stage model of the process was proposed.

Finally, a number of individual differences, in particular, cognitive maturity and problem-solving ability, were investigated in order to determine their influence, if any, on the information retrieval process.

An experimental study was conducted with 254 first year undergraduates in order to test these propositions and constructs.
Results suggested that concept-based teaching was an effective means of developing subjects' knowledge of electronic database searching, and their ability to identify concepts, and construct search strategies, using skills that improve precision (truncation); and recall (Boolean operators). This improved knowledge and skills did not necessarily translate into more successful search outcomes, however, and even taking into account that many subjects would probably improve with practice, the researcher is of the view that a wider range of skills involved with information literacy – including critical thinking, analysis and evaluation – will increase more immediately knowledge of search processes, to result in actual improved search performance. These wider critical thinking skills are investigated in Phase 2.

As with any other discipline, experience plays a role in the development of competence in the information retrieval area; but results from this study suggest that problem-solving ability may be a factor that helps to differentiate novice from expert performance. This finding is important, as problem-solving skills – in the context of information retrieval, an heuristic that assists in the development and execution of a search strategy – can be taught. Results from the current study, regarding the more effective performance of the experimental treatment group on some indicators of search success, support this view.

Further, results suggested that in terms of the thinking capabilities of first year undergraduates, it may be that a significant minority do not possess the cognitive maturity to reason using hypotheses, to determine relevance, to solve problems by analogy, and that these shortcomings in turn influence students' ability to develop complex schemas of the search process, and to structure appropriate problem-solving strategies to run searches. Again, teaching strategies grounded in learning theory, that assist students to understand complexity and to develop mature constructs of subject matter,
may assist the development of a higher level of cognitive maturity, which in turn improves thinking skills and strategies generally.

Finally, the two-stage model of the information retrieval process has some support from the findings of the study. The first stage of the model - involving question interpretation - seems to be assisted by the teaching and modelling of concept identification.

The second stage of the model - running the search - is improved by teaching a problem-solving heuristic, and the modelling of search strategy formulation.

This two-stage model may go some way to addressing the lack of theoretical underpinning for search strategy formulation discussed by Lancaster et al (1994:374):

> Although much has been written on the subject of search strategy, little real research has been done on how different people arrive at alternative search approaches for the same research problem. Even Saracevic et al [1988], while they reported significant differences in approaches, did not try to explain why these differences occur.

Indeed, Saracevic & Kantor (1988) discussed the requirements of a theory of information seeking and retrieving, and suggested that, inter alia, a useful model would have to incorporate elements of context and content of information; and individual differences in patterns of concept formation. Further, Saracevic (1991:85) observed that cognitive theories on “human variability in concept formation, as well as formation of associations, are relevant” to the study of human factors in information retrieval, and that how the search question is represented in memory; selection of subject headings and search terms; how the information is organised; retrieval of items; and judgment of relevance of retrieved items, will have a large impact on
information retrieval effectiveness. Saracevic summarised these factors as “differences and similarities in patterns formed by human minds” (1991:85).

The two-stage model suggested by the researcher may be one possible construct through which to view information seeking and retrieving. The researcher is of the view that the main reason why different people develop different approaches to the search process, and for the relatively small overlap in the selection of search terms for a question by different searchers reported in the literature (Saracevic & Kantor, 1988; Savacevic, 1991; Iiovonen, 1995), is because of their unique patterns of declarative knowledge storage, which influence the first stage of the information retrieval process – problem interpretation, and the naming of concepts identified. This unique way of viewing the research problem inevitably means that every approach to the second stage of the search process – running the search – will be unique. These are the “differences” in patterns formed by human minds referred to by Saracevic (1991).

However, even though every individual will bring unique characteristics to an information retrieval problem, it does not follow that strategies to improve searching in general cannot be taught – and this is where cognitive learning theory, and developmental theory, obtain: they deal with the “similarities” in patterns formed by human minds, referred to by Saracevic (1991).

Indeed, results from the current study suggest that by using concept-based teaching approaches, grounded in learning theory, even in a short module, will improve knowledge of search terms and strategies, and the ability to perform at both the first stage of the information retrieval process, and at the second stage of the process - assisting subjects to develop the knowledge and techniques demonstrated by good searchers. Understanding that in terms of cognitive maturity, possibly up to 20% of first year undergraduates may not be able to reason with abstract ideas and hypotheses, but that these thinking
skills can be addressed with appropriately structured teaching strategies, is also useful.

It was noted at the end of Chapter 4 of this thesis that it has been suggested by some researchers that significant benefits in teaching and learning in higher education may be achieved through the combination of cognitive developmental theory, individual differences, and learning theory (Demetriou, Platsidou, Efklides, Metallidou & Shayer, 1991). The results of the current study support this view.

Results have also suggested a number of areas for further research.

Firstly, as computer literacy and effective end-user computing skills are integral to effective participation in today's information society, further research into these skills as they are represented in the undergraduate population would be useful to assist in developing appropriate courses. Even in 1997, up to 67% of undergraduates surveyed by Tapper, and 76% of those subjects in the current study, had favourable attitudes to computer use, but these favourable attitudes did not always equate, for example, to success in information retrieval tasks, as in the current study. Clearly, other knowledge and skills are required in order to be able to function as information and computer literate professionals.

Secondly, the higher the number of "complex" answers a participant gave on Survey 1, the higher their score in problem solving. The researcher investigated this relationship in a separate study (Macpherson, 2002) and found this relationship to hold for second and third year undergraduates as well as for first year undergraduates.

Thirdly, more effective searchers used better search strategies; they achieved a significantly higher rate of search success than less effective searchers. Was
this because of superior pattern recognition skills? They may have been able to form a more accurate representation of the problem, and so construct more successful search strategies to meet the perceived information need.

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, involving evaluation of sources for credibility and relevance. These aspects of information literacy are explored in Phase 2 of this research, and are reported in Volume II.