Interpreting graphs and tables with cognitive tools

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Interpreting graphs and tables with cognitive tools

A Thesis submitted in fulfilment of the requirements for the award of the
degree of Doctor of Philosophy (PhD)

from

The University of Wollongong

by

Brian Ferry


Faculty of Education

1997
Declaration

I certify that this is my original work and that it has not been submitted for a degree at any other university or institution.

Brian Ferry
24.3.97
I wish to acknowledge the guidance, encouragement and support provided by my supervisors, Associate Professor Barry Harper and Associate Professor John Hedberg.

There are always many others to thank during a project such as this. First, I would like to thank the preservice teachers who took part in this study. Second, I would like to thank Sean Cruickshank, Peter Gracie, Matthew Fifield and Rob Wright for their technical assistance. Also I wish thank my colleagues Christine Brown and Peter Keeble who have provided valuable input at various stages of this study.

Last, but certainly not least, I wish to thank my family Chris, Michelle and Belinda for putting up with the constant talk about this study and the long periods of time that I spent working on this project.
Abstract

This study explores some ways in which cognitive tools may be used to assist learners to interpret graphs and tables. It investigates ways in which concept mapping tools may be applied to this task, and then it investigates how preservice teachers used a suite of simple cognitive tools designed to reduce cognitive load. All cognitive tools were developed with HyperCard™ software and these tools were used by preservice teachers (the subjects of this study).

The thesis is divided into three linked studies. Study 1 investigated the cognitive strategies employed by preservice teachers when they interpreted graphs and tables. The findings were then used to guide the design of the cognitive tools that were used in Study 2.

During Study 1 the ability of various groups of preservice teacher to interpret graphs and tables were compared. The findings showed that when these learners interpreted graphs and tables they had difficulties with understanding the context as described by the accompanying text, sorting and comparing relevant data in tables, and identifying specific global (e.g., slope, turning points, discontinuities) and local features (e.g., labels on axes, points on graphs) that were relevant.

During Study 2 a prototype of the cognitive tools was developed and trialled. These tools were designed to assist learners to interpret information in form of text, graphs and tables that related to the destruction of rainforests. During Study 3 the improved cognitive tools were used by 80 preservice teachers. Interviews, artefacts and tracking data were gathered and used to evaluate the tools.

The findings from all data sources suggest that there are procedures that we should employ to effectively introduce learners to cognitive support tools, as it is not just a matter of designing a suitable tool and then handing it over to the learner to use. Analysis of the concept maps and interview transcripts showed that the learners used one of three strategies to construct their concept maps, but in most cases there was little difference in the quality of the final map produced. It appears that one strength of the concept mapping tool was that it helps learners to visually organise knowledge in different ways. Also the other cognitive tools may have acted as mental devices that supported, guided and extended the thinking processes of learners.
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Chapter 1: Introduction

When William Playfair first discussed the use of graphs to represent information he claimed:

"... I have succeeded in putting into practice a new and useful mode of accounts,... as much information may be obtained in five minutes as would require days to imprint on memory, in a lasting manner, by a table of figures" (Playfair, 1801a, p.12).

Besides demonstrating the value of graphs and charts for displaying data, Playfair contributed to the development of new forms of data display which included the rectilinear coordinate graph, area circle graph, pie diagram and bar chart (Schmidt, 1979). However, it must be recognised that Playfair's work was preceded by many basic developments in mathematics such as the work of René Descartes (Funkerhouser, 1937).

Since Playfair's time, graphs and tables have become a formally recognised and concise way of displaying trends in data. The large number of graphs and tables found in newspapers, magazines, government reports and in science, geography and economics texts show that the authors of these materials think that they are a good way of displaying data and conveying information (Preece, 1985). Weintraub (1967) asserts that "graphs, charts and diagrams have assumed an increasing role in our society. They represent concepts in a concise manner or give at a glance information which would require a great deal of descriptive writing. They often distil a wealth of information into a small amount of space" (Weintraub, 1967, p.345). Despite common usage of graphs and tables, many are not easy to interpret and sometimes they are constructed to be deliberately misleading in order to support the claims of advertisers and politicians (Huff, 1975; Tufte, 1983).

Whilst graphs and tables may be a convenient way to "distil a wealth of information" most people who read graphs and tables in newspapers, magazines and books appreciate that it often requires a great deal of mental effort to interpret the information presented. Readers who are unable to fully process this "wealth of information", often fail to link it with other concepts embedded in their semantic network (Janvier & Garancon, 1989; Janvier, 1978; Preece, 1985). Hence they may not fully understand the issues presented.
In some situations, such as those relating to personal finances and health, accurate interpretation of information presented in tables and graphs becomes essential for informed decision-making. At the macro-level, decisions made by leaders of government and business which affect the lives of citizens are often guided by information presented in graphs and tables. Whilst tables and graphs can be accurate and detailed, there is no guarantee that the consumers of the information will fully understand it or correctly apply it.

**The problem**

When a learner is confronted with unfamiliar information organised in graphical or tabular form, (s)he may find that cognitive strategies that were successful in the past do not help to process the new information. Reasons for this may relate to:

- learner prior knowledge: many researchers claim that learners need help to link new information with prior knowledge so that it becomes embedded into existing schema (Clarke, 1992; Gery, 1989; Jonassen, 1988; Hannafin, 1989; Kenny, 1993; Bonner, 1988; Holley & Dansereau, 1984);

- preferred learning style: researchers suggested that learning styles influence the ways in which learners process information (Dunn, Cavanaugh, Eberle, & Zenthausern, 1982; Kolb, 1984; Claxton & Hurrell, 1987; de Bello, 1990; Dunn, Beaudry, Klavas, 1989; Jung, 1993; Jonassen & Grabowiski, 1993; Schmeck, 1988; Sims & Sims, 1995). Since most learners have preferred ways of learning, then different cognitive (learning) styles require different modes of learning (Romiszowski, 1990; Tyler, 1993; Allinson & Hammond, 1990; Stanton & Baber, 1992; Jonassen & Grabowiski, 1993);

- the complexity of the presentation of the information. If the presentation of information is complex, then the essential message becomes lost because learner attention is distracted by a display of incomprehensible symbols, numbers, lines and labels. This effect is known as cognitive load and has been identified by researchers as a factor that impairs learner ability to interpret graphs and tables (Chandler & Sweller, 1991; Sweller, 1994);
• factors that relate to transfer (Salomon & Perkins, 1989): there are numerous research studies that suggest that learners need help to transfer prior knowledge to new situation (Mayer, 1980; Weingrad, Hay, Jackson, Boyle, Guzdial, & Soloway, 1993; Huberman, 1990; De Corte, 1990; Hannafin, 1989). Since there are alternative paths and many different sets of conditions researchers suggest that transfer may be enhanced when learners are provided with a variety of pathways to follow (Salomon & Perkins (1989),

• other variables such as gender, age, and ability in mathematics.

Learners may find graphs and tables about familiar topics such as the greenhouse effect more understandable than those relating to the formation of minerals from magmas because they have more extensive prior knowledge about the topic. Because they understand the context and the key terms about the greenhouse effect, learners can relate this new information to concepts already held in their semantic memory. However, they are likely to experience difficulty when they are not familiar with the information presented. In order to help learners to process less familiar information, we may provide specific material (e.g. a glossary) about the subject and/or assistance such as a semantic network map or advanced organiser (Ausubel & Youseff, 1963).

On the other hand, there may be learners who are familiar with the subject matter presented, but find the organisation of the information difficult to comprehend, because the explanatory text, graphs and tables use unfamiliar terms, measures and labels. Thus the essential message becomes lost among a display of incomprehensible terms, numbers, lines and labels. To overcome this problem we could simplify and reduce the amount of information displayed, but there is a danger that important details will be lost. We could also provide the learner with human tutorial support, but it is not always feasible to provide a knowledgeable human tutor standing by. Cognitive tools that can be accessed at the moment of need to help the learner read labels and sort variables in numerical order may be an alternative form of assistance.
Definitions of important terms used in the study

In this section a range of definitions for each key term is discussed and then the specific definition chosen for this study is presented. The key terms discussed are: graphs and tables, interpreting graphs and tables, cognitive tools, concept, and concept map.

Tables and graphs

Tables, graphs and diagrams have in common the attributes of abstraction and the exploitation of space (Hegarty, Carpenter, & Just, 1991). However, graphs and tables differ from diagrams because they illustrate relationships among variables whereas diagrams describe processes and structures (Winn, 1987).

Bertin (1983, p.2) defines graphical representation as "one of the basic sign-systems conceived by the human mind for the purpose of storing, understanding, and communicating essential information". Like Playfair (1801b), Bertin also believes that "graphics owes its special significance to its double function as a storage mechanism and a research tool" (p.2). Thus graphics have been regarded for almost two centuries as rational and efficient tools that can be used to present large amounts of information. This broad definition also includes "the fields of networks, diagrams and maps" (p.2). Fields of networks are often described as two dimensional arrangements of words, some of which are joined with lines; diagrams are often described as labelled drawings that are used to convey information about ideas, objects, or processes; and maps are often described as labelled representations of space that can be used to locate one's position or to navigate from one location to another. For the purposes of this study it is important that graphs and tables are clearly identified as separate entities.

Schmidt (1979) describes graphs and charts as presentations "of quantitative data in a simple clear and effective manner and facilitate comparison of values, trends, and relationships" (Schmidt, 1979, p.10). He asserted that:

- "the use of graphs and charts saves time since the essential meaning of large masses of a statistical data can be visualised at a single glance" (p.2);
- visual relationships are more easily portrayed and remembered;
they "provide a comprehensive picture of a problem that makes possible a more complete picture and better-balanced understanding than could be derived from tabular or textual forms of representation" (p.2);

• they "can bring out hidden facts and relationships and can stimulate, as well as aid, analytical thinking and investigation" (p.2).

Frances Curcio (1989) concurs with Schmit's assertions about the advantages of displaying data in the form of graphs and charts. She considers graphs to be an aid for clarifying, organising, and summarising quantitative information.

At times the terms graphs and charts may be used as synonyms and this can lead to confusion. For example, authors describe both bar charts (Schmidt, 1979) and bar graphs (Curcio, 1989, p.3); yet in the context in which they are described they represent the same type of display. Others interchange the terms (Hegarty et al., 1991, p.645).

To avoid any confusion during this study graphs are defined as "forms that illustrate relationships among variables, at least one of which is continuous." (Winn, 1987, p.153). Thus a plot of height with age and a histogram of stream velocity with sediment sizes, and a plot of rainforest area against the name of a country are all graphs.

There is less confusion associated with the term tables and the definition that follows contains the essential elements mentioned by authors in the field (Huff, 1975; Salomon, 1983; Janvier, 1978; MacDonald-Ross, 1977; Winn, 1987; Bowen, 1992). For the purposes of this study tables are defined as displays arranged in rows and columns that illustrate relationships among categorical variables or continuous variables. These rows and columns contain an arrangement of numbers, letters, words, diagrams or a mixture of all of these forms (Winn, 1987, p. 153).

**Interpreting graphs and tables**

Interpreting graphs and tables involves more than the examination of trends; it includes relating trends to explain cause and effect. Janvier (1978) states that "crudely speaking, interpreting a graph consists of putting into verbal form information, regarding a situation, given in a graphical form" (p.3.1). He views the problem in interpreting graphs as associated with the many modes of representation possible. Apart from a
graph, verbal descriptions, tables and formulas are often used to represent the same relationship, and this, he claims, confuses the issue. The research of Chandler and Sweller (1991) supported Janvier’s claim as they showed that poorly organised information causes learners to divide their attention among the various pieces of information and this creates cognitive load which in turn leads to inefficient processing of the information.

Preece (1985) contended that to interpret a graph successfully the learner not only had to read the information contained in the display, but also relate the graph to its context. This view is shared with Janvier (1978); the reader of the graph has to tell the story contained in the information presented. However, some researchers such as Appel (1973) have a narrower definition and maintain that the interpretation of graphs and tables is the ability to read with understanding and to get information that has to do with number values (Appel, 1973). She also contends that it is important to teach skills in graph reading and interpretation. Whilst few would argue with Appel’s suggestion that these skills should be taught, the question of how and when they are taught might be more contentious.

Various researchers who have studied how learners interpret graphs and tables mention the following processes:

1. reading a graph or table (Bowen, 1992; Janvier, 1978);

2. deciphering the labels on axes and the headings of columns (Appel, 1973; Dugdale, 1986; Janvier, 1978; Pinker, 1981; Preece, 1985);

3. describing the global features of the data such as maxima, minima, slope, turning points, regular trends or the means of data presentation such as picture form, bars, columns, lines (Dugdale, 1986; Janvier, 1978, Preece, 1985; van Reeuwijk, 1992);

4. relating the properties of the graphs and charts to information described in accompanying text (Janvier, 1978; Mosenthal & Kirsh, 1991; Roth & Bowen, 1994);

5. application of prior knowledge to aid in the comprehension of the information presented (Janvier, 1978; Preece, 1985; Roth & Bowen, 1994).
The first three points relate to reading or processing of displayed information and the last two points relate to the context in which the information occurs. To correctly interpret a graph or table a person has to read or process the information accurately and then relate it to the context. Figure 1.1 shows a concept map developed by the researcher to explain how this process of interpretation may work.

*Figure 1.1: A model of learner interpretation of information contained text, graphs and tables*

This diagram shows that graphs have two types of visual information; one type is associated with pictures and the other is associated with text and numerical information. Pictures in this context include the global features described previously but may also include iconic labels. Text and numeric features are often found in headings, and on labelled axes but they may be used to direct reader attention to a global feature such as a change in slope or turning point. To successfully interpret a graph the learner has to link both types of information to his/her semantic memory and then construct meaning by relating the features to the context that is usually described by supporting text. Throughout, the prior knowledge of the learner continuously interacts with the interpretation process.
For this study the interpretation of graphs and tables is defined as the ability to read the information contained in the displayed graph or table and to relate it to its context.

To do this successfully a person must be able to read the data portrayed and the labels, relate the labels and data to a specific context, described in the accompanying text, and then translate the meaning associated with the display of the data into words. The process of relating the labels and data portrayed to the context often involves: identification of maximum and minimum; intervals over which the function increases; intervals over which a variable is less than, greater than, or equal to a given constant (plateau); drops and rises of curves between plateaux or extreme points; the general shape (up or down) or curves; discontinuities; patterns that give rise to cycles; steady rates of change; symmetry; extrapolation; interpolation (asymptotes); dispersion of a graph and difference in shape measured by area, and many curves on the one graph (Janvier, 1978). However, this process does not occur in isolation and as Janvier (1978) claims there is no interpretation without regard to the situation. Therefore we must be aware that "any pupil has a personal knowledge...a vast background more or less precisely defined is already present in the pupil's mind before he tackles any question" (Janvier p3.6). While the graph conveys definite information which constitutes a definition of the situation, "this is analysed through a process involving a continuous reference to the underlying background" (p.3.6).

Many previous studies that related to the interpretation of graphs relied upon interviews with a small sample of subjects (less than 25) or survey techniques with a large sample of subjects (over 150). A few studies such as those of Janvier (1978) and Preece (1985) used a combination of these methods. Because of the multiple sources of data used, their studies made significant contributions to our understanding of how learners interpret graphs and tables. Consequently, a similar strategy was adopted during this study.

While this study focuses upon the development of cognitive tools designed to support learners as they interpret graphs and tables, it also builds upon the work of Janvier (1978) and Preece (1985). The cognitive tools were designed to assist learners in the total interpretation process. Therefore the cognitive tools provided assistance in reading data labels and values, in relating the data display to a specific context and with the
construction of a knowledge map that represented the learner's understanding of the information presented.

**Cognitive tools**

David Jonassen (1992b) has described cognitive tools as both mental and computation devices that support, guide and extend the thinking processes of the users. Such tools are external to the learner and are computer-based devices that extend the thinking processes of the learners and engage the learner in meaningful processing of information (Jonassen, 1992b).

For the purposes of this study cognitive tools are defined as: "generalisable tools that can facilitate cognitive processing " (Jonassen, 1992b, p.2). They may make it easier for learners to process information, but their main "goal is to make effective use of the mental efforts of the learner" (Jonassen, 1996, p.10).

Cognitive tools that function as mindtools (Jonassen, 1996) are those that engage the learner in higher order thinking skills such as critical, creative and complex thinking. An example of a mindtool is a computer-based concept mapping tool that learners use for knowledge construction. During the process of knowledge construction learners may employ critical thinking skills to evaluate, analyse and connect concepts and information; creative thinking skills to elaborate, synthesise and visually arrange concepts and information; and complex thinking skills to assess, revise, find alternative structures and make choices.

Cognitive tools that provide "just in time" support (Gery, 1991) are "fingertip" tools (Perkins, 1993) that learners use naturally and effortlessly. They provide context-specific support at the moment of need and balloon help is an example of a "fingertip" tool.

During this study both "fingertip" tools and mindtools were employed to assist learners to analyse and then synthesise information presented as text, graphs and tables.

**Concepts**

The term "concept" has many uses in educational and psychological literature. Some definitions focus on common attributes of objects or events which result in them
belonging to the same category (Frayer, Fredrick, & Klausmeier, 1969). Others focus on the network of relationships between concepts (Anderson, 1980; Novak & Gowin, 1984).

While Novak and Gowin (1984) consider concepts to be "a regularity in events or objects designated by some label" (p.4). For example, the concept "chair" is the label we use in English to designate an object with legs, a seat, and a back that is used for sitting on. That is, the use of the chair was as important as its other attributes. They assert that culture is the vehicle through which children acquire concepts that have been constructed over centuries, and schools are recent inventions for the acceleration of the process of acquiring concepts. When learners begin to construct new knowledge they begin with observations of events and objects and relate this to the concepts that they already hold. Thus "knowledge is not discovered like gold or oil, but rather is constructed like cars and pyramids" (Novak & Gowin, 1984, p.4).

For the purposes of this study a concept represents "anything that can be recognised, that is, that can be attributed identity" (Holley & Dansereau, 1984, p.23). Thus ideas, objects, images, notions, conceptions, beliefs, events, features, properties, and states are examples of concepts. What is commonly referred to as 'having a concept' involves the performance of a combination of generalisation and discrimination behaviour such as classifying correctly any examples of the concept and not including any non-examples, however similar they may be.

**Concept map**

Often children and adults will revert to concrete examples in order to clarify new concepts. During knowledge acquisition learners identify important concepts/ideas in the material and may represent their interrelationships and structure in the form of a network map (Armbruster, 1979; Goetz & Armbruster, 1980; Holley & Dansereau, 1984; White & Gunstone, 1992). The result is a structured two dimensional concept map representing the spatial organisation of the material and "the meaning of each concept is embodied in its relations with other concepts" (Fisher Faletti, Patterson, Thornton, Lipson, & Spring, 1990, p.347). Concept maps can be further elaborated by attaching images, and text (definitions, descriptions, formulae, synonyms or other relevant links).
Figure 1.2 displays a simple concept map. It has a hierarchical structure and the relationship between terms is inclusive, with general ones standing above the specific ones.

*Figure 1.2: A simple concept map (after White and Gunstone, 1992)*

![Concept Map Diagram]

Researchers such as: Novak (1990); Jegede, Alaiyemola, and Okebukola, (1990); Jonassen (1992a); and Lloyd (1990) share the view that concept mapping helps learners organise their cognitive frameworks into powerful integrated patterns.

**Purpose of the study**

This study sought to develop and evaluate a set of cognitive tools designed to assist learners to process information presented in text, graphs and tables. The text, graphs and tables were presented on an Apple Macintosh™ computer platform and the cognitive tools were developed using a HyperCard™ programming environment.

The cognitive tools were to serve three basic functions: first the tools were to assist the learner to read and compare the values presented in the graphs and tables; second they were to help the learner to relate the data to a specific context that was described in the accompanying text; and third they were to provide a mechanism for the translation of meaning associated with the data into words.

The graphs and tables used in this study were not presented in isolation from their context. They related to the specific topic of rainforest destruction and text was included with the graphs so that the learner could relate the context and the data presented.
Theoretical perspective

The theoretical perspective adopted during this study is based upon a constructivist philosophy which asserts that we can only know about reality in a personal and subjective way (von Glaserfeld, 1989). Thus each person's experiences dictate how (s)he interpret the world and the knowledge (s)he constructs from these experiences is based upon both individual and social interaction (Cannon, 1995). A constructivist approach to learning is based upon the supposition that learning is "the product of self-organisation" (von Glaserfeld, 1989, p.136) which occurs as the learner interprets new experiences by relating them to past understandings. This process of learner self-organisation may occur alone or in a social setting such as a classroom or in the home.

Constructivist learning theory recognises that each learner has a unique experience of the world and this influences how (s)he organises these experiences into knowledge structures and beliefs. Furthermore, these personal (and often idiosyncratic) sets of knowledge structures and beliefs strongly influence the way in which (s)he interprets new learning experiences (Cannon, 1995; Jonassen, 1996). Learning experiences that are based upon constructivist theory acknowledge that learning is a purposive process and learners are ultimately responsible for the knowledge they construct (Driver et al., 1994). Since prior conceptions brought to learning situations influence what is learnt, the approach requires learners to be actively involved in the process of construction of meaning which often takes place through interpersonal negotiation (von Glaserfeld, 1989).

This study focuses on two aspects that relate to a constructivist perspective on learning. First, the processes involved in the design and modification of the cognitive tools employed during this study, and second, upon the learner interactions with these tools as they generate their own understandings from the information presented. The outcomes from this study may stimulate instructional designers to develop more cognitive tools from a constructivist perspective, and researchers to investigate new research questions. Ultimately it should be the learner who benefits most from the outcomes of this study.

An important aspect of the cognitive tools investigated in this study was the facilitating role they can play. Simply providing learners with tools to process information is not
enough, the learning environment in which the tools are used also has to be considered. This notion is supported by authors such as Jonassen (1996) who claimed that cognitive tools will have their greatest effectiveness when they are applied within constructivist learning environments. He asserted that cognitive tools should enable learners to create their own representations of knowledge rather than absorbing knowledge representations created by others. That is, cognitive tools can support the deep reflective thinking required for meaningful learning. Furthermore, the technology of the computer and its associated software form an intellectual partnership with the learner and this in turn creates a cognitive residue that remains after the cognitive tools are used.

The inquiry techniques employed during this study required a judicious mixture of context specific methods that meet the unique requirements of the specific research questions. Multiple data gathering techniques were needed to ensure that the data were comprehensive, reliable and valid. Data were gathered from: interviews; computer monitoring of subject use of software (tracking data); surveys, and analysis of concept maps created by the learners.

**The cognitive tools**

Rather than develop one specific tool, it was decided to develop a suite of cognitive tools that could be used in a more realistic learning situation where text, graphs and tables were used together to present information to learners. The tools developed were designed to serve two broad purposes. First tools were developed to assist learner analyse information presented in text, graphs and tables; and second a concept mapping tool was developed to assist learners synthesise information presented in text, graphs and tables.

These cognitive tools were developed with HyperCard™ software, a software product for Apple Macintosh™ computers. It has many applications some of which include: screen painting; database management; a programming language; a tool set; a resource library, and an operating shell that can be used to make multimedia productions.

All of the tools developed made use of on-screen buttons. A button in HyperCard™ applications is an on-screen area that is activated when a learner uses the mouse to move the pointer over this area (which may be visible or invisible to the user) and presses the mouse button once.
The cognitive tools developed to analyse information were to serve three basic functions: first the tools assisted the learner to understand the meaning of key words presented in text; second they assisted learners to read and compare the values presented in the graphs and tables; third they allowed to learner to relate the data to a specific context. The concept mapping tool provided a mechanism for the translation of meaning associated with the data into words.

1. **Understanding the meaning of words presented in text**

   Explanatory text that accompanied the graphs and tables contained key concepts that were colour coded. These concepts were linked to a glossary that could be accessed when a learner used a mouse to click on these colour coded words.

2. **Reading and comparing values presented in graphs and tables**

   The tool used with the table was a simple sorting tool that allowed the user to sort the data in each column in descending order. To activate this function the user clicked on the column headings.

   The tool used to assist with the reading of graphs was in the form of balloon help. This tool was automatically activated when the cursor was positioned above a labelled section of a graph. Then a balloon containing some explanatory text appeared.

3. **Relating the data to a specific context**

   Once again balloon help was employed to display location maps of the countries listed on the axes of the graphs. A location map appeared when a user moved the cursor over the name of a country.
4. The translation of meaning associated with the text, graphs and table into a concept map

Of the tools developed this presented the greatest challenge because it involved the use of the concept mapping tool as a means of translating data presented in text, graphs and tables into a knowledge structure. The concept mapping tool developed allowed learners to make a list of concepts and to draw links among them. They could also add explanatory notes to the links and to the concepts. The concepts and attached notes could be re-arranged, modified and linked into a comprehensive concept map that represented learner understanding of the information presented. This information could be saved as a text file and imported into a word processor application where it could be developed into a short explanatory essay. Therefore the concept tool was used a means of integrating the various sources of information in order to generate a written summary which reflected the current understanding of the learner.

Research questions and strategies

The research questions posed were:

1. What factors affect the ability of various groups of preservice teachers to interpret a set of graphs and tables?

2. What cognitive strategies do preservice teachers employ when they interpret graphs and tables?

3. How do the identified cognitive strategies compare with those strategies identified by other researchers?

4. Could the instructional strategies identified by researchers in related fields be applied to effectively introduce learners to the concept mapping tool?

5. What effect does the concept mapping support tool have upon the way the learners structure their knowledge?

6. Do the cognitive support tools assist learners to analyse information in text, tables and graphs?
7. What evidence is there that these cognitive tools had an impact upon the concepts developed by the learners?

8. Do the tracking data help researchers in understanding the way in which the tools were used?

9. How did the learner access information?

**Brief discussion of the research questions**

Research questions 1, 2 and 3 are discussed together.

1. What factors affect the ability of various groups of preservice teachers to interpret a set of graphs and tables?

2. What cognitive strategies do preservice teachers employ when they interpret graphs and tables?

3. How do the identified cognitive strategies compare with those strategies identified by other researchers?

This part of the study focused on the research strategies employed by learners as they interpreted graphs and tables.

Three broad research strategies were adopted: the first was a review of studies already undertaken; the second was a quantitative approach that formulated and tested hypotheses that predicted relationships independent and dependent variables; and the third used a qualitative approach that relied upon interview data gathered from a small sample of subjects.

4. Could the instructional strategies identified by researchers in related fields be applied to effectively introduce learners to the concept mapping tool?

Research strategies 3, 4, 5, and 6 were adopted to investigate this research question. The concept mapping tool was developed to help learners synthesise the data presented in graphs and tables into a semantic network that reflected each subject's current understanding of the topic. Hence the use of concept mapping tool as a strategy to assist in the knowledge construction process was a critical part of this study.
However, before the concept mapping tool was used it was necessary to provide the subjects with some experience with the process of concept mapping. Researchers have suggested that a period of direct instruction is needed before learners can successfully employ this process (Harlen, 1992; White and Gunstone, 1992), but it is claimed that after total of two hours of instruction and practice adult learners become proficient in developing concept maps (Martin, 1994, pp. 13-14).

5. What effect does the concept mapping support tool have upon the way the learners structure their knowledge?

The research strategies adopted were associated with strategies 3, 4, 5 and 6 listed previously. Data from concept map analysis, interviews, and tracking files were used. The data from the concept maps and tracking data were analysed first and trends that emerged from this data were used to guide the formulation of additional questions asked during interviews. The transcripts from the interviews were then analysed to verify any emerging trends. Also any new trends that emerged from the interview transcripts were verified by re-examination of the other data sources.

6. Do the cognitive support tools assist learners to analyse information in text, tables and graphs?

The cognitive tools designed to assist learners to analyse information in text, graphs and tables were the glossary, the questions, the sorting tool and the balloon help. It was anticipated that the organisation and timing of the interviews would be of critical importance to the quality of the data obtained.

7. What evidence is there that these cognitive tools had an impact upon the concepts developed by the learners?

This part of the study examined the ways in which information about rainforest destruction was accessed, what cognitive tools were used and whether this information had an impact upon the concepts developed by the preservice teachers. The data from the interviews and the concept maps were analysed, and where appropriate, supplemented with data from the tracking files.
8. Do the tracking data help researchers in understanding the way in which the tools were used?

The tracking data were collected automatically after the user logged on to the software. A large amount of data could be gathered automatically, but a large volume of reliably collected data does not necessarily equate with useful and interpretable information and other data sources such as interviews and observations were used to verify the tracking data.

9. How did the learner access information?

A variety of research approaches were employed in answering this question. First multiple regression analysis of survey data and tracking data was used to determine if there was any relationship among any of the independent variables (attitudes to computers score, gender, age, preferred learning style), and the dependent variables (total time spent using the application, and the frequency of subject referrals to specific screens of information). Interviews and observations were also used to verify these findings.

Data sources and research strategies

During this study six research strategies were employed to gather reliable and valid data and these are briefly described.

Research strategy 1: A review of the literature

This section consisted of two chapters each of which was divided into two parts. The first part of Chapter 2 reviews relevant learning theory that supported this study. The second part of Chapter 2 discusses relevant models of how learners assimilate and accommodate new information into their existing schemata. In Part 1 of Chapter 3 relevant studies relating to the interpretation of graphs and tables are examined, and in Part 2 of Chapter 3 the findings from the previous sections are synthesised and applied to the problem of designing cognitive tools that assist learners to interpret graphs and tables.

Research strategy 2: Questionnaires and tests

Questionnaires and tests were used to ascertain the ability of the subjects to interpret graphs and tables. Data for other variables that may affect the ability of subjects to interpret graphs and tables were gathered from university records or from questionnaires
and tests. Where appropriate, multiple regression analysis was then used to identify any significant relationships among the variables.

**Research strategy 3: Interview methods**

Interviews were conducted with a sample of subjects who completed a test on interpreting graphs and tables, and with subjects who used the cognitive tools. These interviews were to verify data collected by other methods and to identify any emerging trends.

**Research strategy 4: Tracking files of learner use of the software**

Tracking files of learner use of the software were recorded on a file server. This file was created when a learner logged on to the software. The file contained information about the frequency and time that the cognitive tools were activated. Multiple regression analysis was used to identify any relationships between the independent variables and the tracking data. The tracking data was also compared to the other sources in order to identify or verify any emerging trends.

**Research strategy 5: Analysis of learner-created concept maps**

The concept maps created by learners were automatically recorded on the file server when they quit the software. These were analysed and compared with the other data collected in order to identify or verify any emerging trends.

**Research strategy 6: Observations of learner use of the software**

The researcher took a voice-activated micro cassette audio recorder to all laboratory sessions. Spoken observations were recorded when the need arose.

**The subjects**

All subjects of this study had completed a one semester subject in information technology, and could use an Apple Macintosh™ computer. They could switch it on, use a mouse, load and save software, print out documents, and safety shut down the computer. The reading level of the subjects was equal to or greater than a Fry Readability index (Fry, 1977) that gave a value in the year 10 age group (16 to 17 year old reading level).
Limitations

The following points need to be made about the limitations of the study.

1. The study was limited to subjects who were years 1, 3 and 4 preservice teachers. Researchers who intend to apply the findings to other contexts would need to view the findings from this perspective. The research strategies and cognitive tools developed may be applicable to other contexts, and the findings may support and extend the work of previous researchers in the field, but specific findings may be unique to the population studied.

2. The cognitive tools developed were used with bar graphs only. While the tools can be applied to line graphs as well as other forms of graphs, no claim can be made about the general applications without further studies with different forms of graphs.

3. The graphs and tables related to the topic area of rainforest depletion. No claim can be made about the success of this approach to other topic areas without further studies.

4. The type of cognitive skills involved in the interpretation of graphs and tables were identified through the literature review and then verified by the findings from the first part of the study. These skills fell into three broad categories: reading and comparison skills needed to identify individual values and trends presented by the data displayed in the graphs and tables; reading comprehension skills needed to relate the data to its context; and translation skills needed to the articulate the message conveyed by the data into words. These skills are in reality an external manifestation of much a deeper level of cognitive processing within the human brain, but the investigation of this aspect of cognitive processing is beyond the scope of this study.

Significance of the study

The study has significance from four perspectives. First, the findings should add to our understanding of learner use of the specific cognitive tools designed to assist them to
interpret graphs and tables. The identification of use patterns and strategies employed by learners should guide future refinements of these tools.

Cognitive tools have the potential to play a significant role in the reduction of cognitive load associated with many information processing tasks, but they can do the reverse if poorly designed. If the use of the tool creates significant cognitive load on the learner, then its use may be counter-productive. During this study the cognitive tools were designed with this perspective in mind. The methods employed and the findings from this research should provide some assistance to instructional designers, other educational practitioners, and researchers as they develop and evaluate cognitive tools in similar contexts.

Second, the findings related to the development of the cognitive tools may stimulate others to follow a similar research path and to build upon the findings of this research. Instructional designers, other educational practitioners and researchers may wish to improve on the cognitive tools developed for this study or modify them to apply to other contexts.

Third, the findings should add to our understanding of how learners employ the previously discussed cognitive skills to interpret graphs and tables. The studies of Janvier (1978) and Preece (1985) demonstrated how multiple sources of data may be used to make a significant contribution to our understanding of how learners interpret graphs and tables. This study builds upon their work and adds an additional source of data.

Fourth, the research methods employed should benefit others in the field. Researchers should be able to evaluate the effectiveness and efficiency of the methods employed and modify or re-apply them to their contexts.

Outline of the structure of the remainder of the thesis

This thesis consists of eight chapters: the contents of Chapters 2 to 8 follow the structure as shown below.

Chapter 2 - Supporting Educational Theory and Chapter 3 - Learner Interpretation of Graphs and Tables.
The purpose of these chapters is to provide theoretical guidance for the design of cognitive tools that assist learners to process and construct meaning from information presented in the form of text, graphs and tables. It was important to examine previous studies about the interpretation of graphs and tables that were relevant to the context of this study as not only are they a source of appropriate research techniques, they are a source of data that can help in the development of suitable cognitive tools.

Chapters 2 and 3 each contain 2 parts. Part 1 of Chapter 2 discusses learning theories that relate to the context of this study. In particular it examines the contribution of cognitive learning theory to our understanding of how learners process information in the form of text, graphs and tables. Part 2 presents researcher-based models of how learners assimilate and accommodate new information into their existing schemata. In Part 1 of Chapter 3 research findings that relate to the interpretation of graphs and tables are examined. It identifies structural features of graphs and tables that researchers claim supports learner processing of information. Also this section describes in general terms a theoretical model of learner interpretation of graphs. Finally, in Part 2 of Chapter 3 the findings from the previous sections are applied to the designing appropriate cognitive tools. This part then concludes with a brief discussion of the research questions that emerge from the review of the literature.

Chapter 4 - Methodology: An overview of the three studies

This chapter summarises the methods used to gather and analyse data. It also outlines the way in which the cognitive tools were developed and modified. The chapter begins with a description of an annotated flow chart that provides an overview of the studies. Also it includes a diagram that describes the data gathering events.

There were three sequential studies. Study 1 investigated learner interpretation graphs and tables. Study 2 developed and evaluated a prototype of cognitive tools designed to assist learners to interpret graphs and tables, and Study 3 investigated learner use of the concept mapping and information handling cognitive tools.

Chapter 5 - Study 1: Interpreting graphs and tables

This chapter examines how learners interpreted graphs and tables and the findings related to research questions 1, 2, and 3.
Chapter 6 - Study 2: Learner use of the prototypes of the cognitive tools.

These data were to be used to further refine the cognitive tools and contributed toward the understanding the research questions 4, 5, 6, 7, and 8, but these questions were treated in much greater depth in Study 3.

Chapter 7 - Study 3: Use of the concept mapping and information handling cognitive tools.

This chapter examines learner use of the refined version of the concept mapping tool. Also presented are data arising from preservice teacher use of the refined version of the analytical (or "finger tip") cognitive tools developed to enhance their understanding of rainforest destruction. The data contributed to the understanding of research questions 6, 7, 8 and 9.

Chapter 8 - Discussion and Conclusion

This chapter discusses the results presented in Chapters 5, 6, and 7, and relates them to the research questions, the literature review and research methods employed. As each research question is discussed, related theoretical and methodology issues are raised. Also the limitations of the current study are discussed and avenues for further research identified.

In addition, this chapter discusses issues that need further investigation and makes suggestions for future studies. Also it discusses future uses of cognitive tools to support education and learning.
Chapter 2: Supporting Educational Theory

The previous chapter explained that this study sought to develop and evaluate cognitive tools that would assist learners to process information presented in text, graphs and tables. The purpose of this review of relevant research is to provide theoretical guidance for the design of cognitive tools that assist learners to process and construct meaning from information presented in the form of text, graphs and tables.

The supportive theory is based upon a constructivist epistemology. Although constructivism is not a new philosophy of learning, there are now efforts to understand the application of constructivist principles across all areas of education (Tobin, Tippins & Gallard, 1994). This review develops an understanding of how this approach can be applied to help learners interpret graphs and tables.

This chapter is structured in two parts. Part 1 discusses learning theories that relate to the context of this study. In particular, it examines the contribution of cognitive learning theory to our understanding of how learners process information in the form of text, graphs and tables. The processing of information in the form of text is also included as graphs and tables are typically accompanied by explanatory text that describes their context. Part 2 presents researcher-based models of how learners assimilate and accommodate new information into their existing schemata. It concludes with a summary that relates these ideas to the context of this study.

Part 1: Relevant theoretical models of learning

In this literature review, theoretical models of learning that assist researchers to understand how learners process graphical and tabular information are discussed and where appropriate relevant models relating to the processing of text are also included. The focus is on educational and psychological theories that can provide guidance in the design of cognitive tools which assist learners in the interpretation of text, graphs and tables.

When a learner interprets graphs and tables, (s)he may find that familiar cognitive strategies such as those used when reading text are not as successful in this context. Several reasons have been proposed for this and these include the learner's prior
knowledge, preferred learning style, the complexity of the presentation of the information (the text, the graph or the table), cognitive load (Chandler & Sweller, 1991) and factors that relate to transfer (Salomon & Perkins, 1989).

Let us consider a specific example, of graphs and tables that relate to the formation of metal alloys. It soon becomes clear that much of the information cannot be fully understood without prior understanding of specialised terms such as alloy, phase, eutectic, eutectoid, liquidus, solidus, and solvus. Once learners understand these terms, they can relate this information to their existing semantic network. To help learners to process this unfamiliar information, we may provide specific information about the subject and/or assistance such as a semantic network map or advance organiser (Ausubel & Youseff, 1963).

On the other hand, learners may be familiar with the subject matter presented, but find the presentation of the information confusing, because the text, graphs and tables use unfamiliar measures and labels. Then the essential message becomes lost because learner attention is distracted by a display of incomprehensible symbols, numbers, lines and labels. This effect is known as cognitive load and has been identified by researchers as a factor that impairs learner ability to interpret graphs and tables (Chandler & Sweller, 1991; Sweller, 1994). To reduce this effect we could simplify or reorganise the information displayed, but there is a danger that the message conveyed will be lost. We could provide learners with tutorial assistance, but it is not always feasible to have a knowledgeable human tutor standing by to lend assistance. Therefore, other forms of assistance need to be considered.

Various researchers argue that it may be important to provide the learner with strategies that help him/her to assimilate data from sources such as graphs and tables to his/her existing semantic network (Quillan, 1968; Holley & Dansereau, 1984; Heimlich & Pittelman, 1986; Clarke, 1991; Mayer, Dyck & Cook, 1984; Bean, Singer, Sorter & Frazee, 1986; Ausubel, 1960; Mayer, 1975; Mayer, 1976; Mayer, 1977; Mayer, 1979). One such mechanism may take the form of a semantic network map or post-organiser (Heimlich & Pittelman, 1986; Merrill & Stolurow, 1966).
An additional way to assist learners to interpret text, graphs and tables may be through an electronic support system (EPSS) which provides learner access to required help at the moment of need (Gery, 1989; Clarke, 1992). Such a support system provides at the moment of need the essential knowledge needed by the learner to understand the information and the underlying message conveyed by the data presented. Only learners who require support access it, so the responsibility for obtaining help lies with the learner.

Gery (1989) asserts that if the learner is provided with an EPSS that provides additional knowledge at the time of need, then (s)he can make progress in learning. She demonstrated that computer-based monitoring of performance can provide intelligent advice that assists worker productivity. This form of support may be effective in industrial contexts where subjects are adults who have to perform specialised and well-defined tasks, but it may be less effective in school-based learning situations, where the learning tasks are not as well defined and transferable generic skills are often more important than specific procedural knowledge. Since, the context of this study is different to those of Gery, direct transfer of her ideas may only apply to specific situations.

Another approach is to use a more general form of cognitive support and during this study cognitive tools were developed for this purpose. The generic term 'cognitive tool' (Jonassen, 1992b, p.2) describes devices that facilitate cognitive processing of information and is the term adopted for this study. Cognitive tools are both mental and computation devices that support, guide and extend the thinking processes of the users and are external to the learner. They also engage the learner in meaningful processing of information (Jonassen, 1992b). In 1996 David Jonassen employed the term Mindtools to refer to "computer applications that require students to think in meaningful ways in order to use the application to represent what they know" (Jonassen, 1996, p.3). He argues that in order to use such tools learners have to engage their mind and become involved as active constructors of their own understanding and knowledge. That is, the learner forms "an intellectual partnership with the computer" (p.4).

Visual tools as described by David Hyerle (1996) are cognitive tools that can be used to reflect our capacities to pattern and reorganise relationships (Hyerle, 1996). He classifies
such visual tools into three basic categories "brainstorming webs, task-specific organisers, and thinking-process maps" (p.3). A computer based concept mapping tool was used by learners during this study to construct knowledge. According to Hyerle (1996), this tool is classified as one that creates a thinking-process map whereas Jonassen (1996) would use the generic term mindtool.

Guidance from educational theory

In 1977 Joseph Novak stated that "the development of interpretive models is needed and can be valuable to the advance of educational practice, provided we recognise the tentative and evolutionary character of the concepts we derive from them." (Novak, 1977a, p.20). In the context of this study the theoretical models of learning reviewed were used to identify principles of instructional design that applied to cognitive tools developed for specific tasks associated with learner understanding of graphs and tables. These tasks were first identified after reviewing relevant studies associated with the interpretation graphs. They were then verified when the researcher sought to replicate aspects of studies reviewed in the literature.

Most researchers classify learning theories into two broad groups known as behavioural and cognitive (Bigge & Shermis, 1992). As with most human classification schemes, some overlap occurs, and later in this chapter Gagné’s eight principal categories of learning outcomes are used as an example of the overlap and evolution in ideas toward a cognitive perspective. In this section it is argued that behavioural and cognitive theories apply to different aspects of the design of computer-based instructional materials, and embedded within these broad categories are other theories that can be considered as subsets.

Relevant aspects of behavioural theory

While behaviourism may be less fashionable today, a review of supporting theory would be incomplete without a mention of the contribution of behavioural theory.

Behavioural psychology is based on experimentalism that has as its origins the methods promoted by Francis Bacon (1620) over 370 years ago. Twentieth century behaviourist learning theory has as an experimental research base the results of numerous studies of
stimulus-response relationships and reinforcement such as those of Pavlov, Watson, Thorndike and Skinner (Lefrancois, 1972; Skinner, 1958).

The behavioural model of learning can describe simple learning situations where the stimulus and the response are easily identified, but as one progresses to higher order learning in human subjects, it becomes increasingly difficult to describe the outcomes completely in terms of patterns of Stimulus-Response connections. Most cognitivists would say that this is impossible to do (Romiszowski, 1990) and would argue that behavioural models of learning fail to recognize the complexity of the interactions among the experimenter and the variables, the changes in those interactions produce in the variables, and the concepts that govern their interpretation. Also, there are many antecedent conditions that affect a learning situation and these cannot be accounted for (Novak, 1977a).

Past studies that focused upon behavioural models of learning were usually quantitative and based upon some form of comparison between experimental and control groups. The findings from such studies have limited application because of the reasons previously mentioned, but there were some successful applications associated with drill and practice software. Whilst many of these early attempts were criticized as boring and lacking in strategies to motivate students (Sewell, 1990), others could be effective in narrow applications such as drill and practice associated with the learning of multiplication tables or spelling rules (Price, 1991). Therefore, drill and practice software should be considered as a legitimate application of behavioural education theory to the design of computer-based instructional systems, but the context is limited to specific situations where learning outcomes are observable and measurable.

Relevant aspects of cognitive theory

The limitations of behavioural theory made researchers look more closely at other theoretical models of learning and thus cognitive theoretical models such as those of Piaget (1971) and Bruner (1966) received more attention. Bruner's theory of instruction as presented in "Towards a Theory of Instruction" (1966) is an example of a cognitive theory that has application in this area. He states that a theory of instruction should take into account: the nature of persons as knowers; the nature of knowledge, and the nature
of the knowledge-getting process. For Bruner, a theory of instruction should cover five main aspects of learning:

1. optimal experiences that predispose learners to learn. As Bruner (1966) states "Learning and problem solving require the exploration of alternatives. Instruction that is geared to promote this function should minimise the risk involved in exploration; it should maximise the informativeness of error, and should seek to weaken the effects of previously established constraints on exploration and curiosity ..." (p.198);

2. structuring knowledge for optimal comprehension. He states that "grasping the structure of a subject is understanding that it in a way that permits many other things to be related to it meaningfully"(p.7). Hence, knowledgeable experience should be coded in such a way that it is useable by students in both present and future learning and living situations;

3. organisation of the materials to be learnt into optimal sequences of presentation. Bruner argues that the task of instructors is to convert knowledge into structures that are within the grasp of learners at various ages and to arrange the structures in an optimum sequence of materials to be learnt. The reverse of this approach is to provide the learner with tools that allow him/her to arrange learning materials into meaningful knowledge structures and cognitive tools are designed to assist learners to provide this function;

4. the role of success and failure and the nature of reward and punishment. Rewards and punishments associated with learning are seen as motivators that affect the informative utility of successful and unsuccessful attempts at problem solving. Such successes and failures in learning may lead to: more rapid awareness and understanding; a feeling of capability associated with the challenge of exercising one's full mental powers; a development of interest and involvement; the pleasure gained from mastery of a cognitive task; a sense of achievement, and the development of 'reciprocity' - deep human need to respond to others and to operate jointly with them;

5. procedures for stimulating thought in a school setting. Bruner believes that "if information is to be used effectively, it must be translated into the learner's way of solving a problem" (Bruner, 1966, p.53). Therefore instruction should "make the learner
or problem-solver self-sufficient." (Bruner, 1966, p.53). Again cognitive tools are designed to support the learner in becoming a self-sufficient problem solver.

Later in this study the principles identified by Bruner were applied to the design and introduction of cognitive tools.

Research associated with cognitive learning theory is usually qualitative because it lends itself to a holistic approach that views learning from multiple perspectives, and reflects the complexity of the interactions between those involved in the learning process. Whilst the problem of generalisable findings exists, there is value in qualitative studies that focus upon subjects in natural settings. A limited discussion of a number of significant researchers whose works are relevant to the context of this study follows.

**The contribution of Jean Piaget**

Piaget studied the nature of children at different ages and focused upon the innate development stages of children as they relate to their acquisition of knowledge. It has been argued that the contribution of Jean Piaget to the understanding of learning was more in developmental psychology than in learning theory (Bigge & Shermis, 1992). For Piaget, the mental development of any child consisted of a succession of stages or periods. Each stage extends the preceding stage, reconstructs cognition on a new level, and comes to surpass the earlier stage.

The key processes in the stages of child development are assimilation and accommodation. Assimilation consists of filtering or modification of the input from the environment. In this process new knowledge is assimilated with the child's previous experiences. Accommodation consists of the modification or change of the child's internal patterns of understanding to fit reality. During this process existing internal insights are reconstructed so as to "accommodate" new data or information. It is the key processes of assimilation and accommodation that provide theoretical support to the experimental research involved in this study.

However, Piaget was criticised by some researchers as they claimed that his theory limited his interpretation of his interview data (Novak, 1977a; Donaldson, 1978; Modgil & Modgil, 1982; MacNamara, 1982). Also they have claimed that he failed to recognise adequately the powerful roles that language development and specific frameworks of
relevant concepts play in the development in the pattern of children's reasoning. This is an important criticism as many researchers have shown that language plays an important role in the development of concepts (Garton, 1992; Lozanov, 1978; Osborne & Wittrock, 1985; Vygotsky, 1978). Nevertheless, these criticisms do not detract from prudent adoption of his ideas in a new context, as the postulated processes of assimilation and accommodation enable us to form a mental model of the learning process, and to develop an understanding of what happens when learning occurs. Von Glaserfeld (1989) argues that "knowledge for Piaget is never (and can never be) a representation of the real world. Instead it is a collection of conceptual structures that turn out to be adapted or, as I would say, viable within the subject's range of experience" (p.125) and "learning is the product of self-organisation" (von Glaserfeld, 1989, p.136).

Seymour Papert and the idea of constructionism

The work of Seymour Papert forms part of this review because of his significant contribution to the use of computers as learning tools. His work is presented at this stage of the literature review as Papert was strongly influenced by Piaget.

Papert believed "that certain uses of very powerful computational technology and computational ideas can provide children with new possibilities for learning" (Papert, 1980, p.17) and asserted that computers "should serve children as instruments to work and to think with, as the means to carry out projects, the source of concepts to think new ideas." (Papert, 1993, p.168). He admitted that he was strongly influenced by Piaget's notion that 'to understand is to invent' in a new domain (Papert, 1993, p.169). In this way knowledge becomes useful and can be shared with others.

Papert argued that the notion of "different ways of knowing" was the most important contribution of Piaget. Furthermore these "different ways of knowing" are used by learners to solve real world problems every day. He prefers to use the term "constructionism" (Papert, 1993, p.142) to describe the intellectual processes involved in the reconstruction of knowledge for specific purposes. Often this knowledge is not learned at school and does not conform to the traditional school-based notion of what proper knowing is. The learner uses an idiosyncratic set of cognitive tools in this reconstruction process. While his ideas appear to be part of a 'constructivist' approach to
learning (discussed later in this chapter), he claims that his term is a "personal reconstruction of constructivism" (p.142) and is different. Papert asserts that constructivism expresses the theory that knowledge is built by the learner and not supplied by the teacher, and constructionism expresses the further idea. That is, knowledge construction happens felicitously when the learner is "engaged in the construction of something external or at least shareable... a sand castle, a machine, a computer program, a book ..." (p.142). The construction of a concept map that reflects a learner's understanding of a specific domain of knowledge would also be an example. Such a map may represent a learner's cognitive structure or "cognitive scaffolding" (Ausubel, 1968). A discussion of Ausubel's work follows as his research inspired the application of his theory to the procedure of concept mapping by Novak and Gowin (1984).

**Ausubel - supplying a cognitive structure**

Ausubel argued that the provision of cognitive scaffolding supports learners when they acquire new information, and the idea of an advance organiser developed from his research (Ausubel, 1960; Ausubel & Youseff, 1963; Ausubel, 1968). Various claims have been made about the effectiveness of advance organisers (Clarke, 1991; Mayer, 1980; Mayer, 1975; Merrill & Stolurow, 1966), and several reviews of research findings reported small improvements in learning across all content areas (Luiten, Wilbur & Ackerson, 1980). Others have concluded that "the efficacy of advanced organisers has not been established" (Barnes & Clawson, 1975, p.651). It may be more productive in the context of this study to acknowledge this debate rather than participate in it. Rather the focus for this study is upon the essence of Ausubel's theory as summarised by his statement that "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Ausubel, 1968, preface page vi). Thus, to apply this idea, we must identify the relevant concepts that are part of the learner's existing knowledge or, as Ausubel explained, identify the relevant subsuming concepts that are available in the learner's cognitive structure.

Ausubel conceived of cognitive structure as highly organised linkages formed between information stored in the brain. While such a structure is idiosyncratic, it is highly ordered, forming links between various older and newer elements of knowledge.
(concepts). This conceptual hierarchy contains minor elements of knowledge that are linked (subsumed) under more general, more inclusive concepts.

Thus a cognitive structure represents a framework of hierarchical organising concepts which depict an individual's organisation of experience. Every individual has a unique history and an individual's cognitive structure relates to their life experiences.

As new experiences are acquired, new knowledge is related to concepts already in a person's cognitive structure. These concepts become elaborated or altered so that they can be linked to a wider array of new information in subsequent learning. Such a process is described by Ausubel as concept differentiation (Ausubel, 1963). This aspect of Ausubel's work suggests that it is not a simple task to ascertain what the learner already knows. Therefore we may need to look at the problem of ascertaining what the learner already knows from a different perspective as traditional methods of testing reveal little, if anything about the learner's cognitive structure. Concept mapping developed as an alternative strategy that could be used to obtain a representation of a learner's cognitive structure (Novak & Gowin, 1984).

The second part of Ausubel's statement about learning mentions to "teach him accordingly". Individuals can learn information that bears little or no association with existing concepts, but Ausubel argues that meaningful learning occurs when new information is linked with existing concepts. When this happens he claims that the new information is more likely to be successfully retrieved from long-term memory.

When we apply this principle, Ausubel suggests that we might begin instruction with the most general concepts, but we need to show how they are related and need to move up and down the concept hierarchy in order to illustrate links between concepts. Such an approach is called expository teaching. While other researchers supported the notion that learning materials should be ordered in some sort of discipline-determined logical order they reported no evidence to support the use of an organisational structure based upon psychological factors (Holley & Dansereau, 1984; Bigge & Shermis, 1992).

Other theories of learning were proposed and some evolved to consider learning from the perspective of information processing. Robert Gagné is an example of a researcher who now considers learning from an information processing perspective and his theoretical
approaches serves to illustrate how the ideas of established researchers continue to evolve as they struggle to understand human learning. His hierarchical model of learning was a neo-behaviourist model that drew upon behavioural theory up until a certain stage (step 6), but then it adopted a cognitive approach. More recently Gagné moved toward an information processing model of instruction as discussed in Gagné, Briggs and Wagner in their 1988 edition of "Principles of Instructional Design".

The use of information processing models of learning

Information processing models of learning make use of a computer metaphor to model human processing of information. It has proved to be an important strategy for research in cognition especially in the areas of attention, memory and problem solving. The emergence of information processing models coincided with the decline in Piaget's influence and the turning away from earlier theories of cognition such as Ausubel's.

The major objective of information processing models is to trace the flow of information through space and time through a processing system. Such a human information processing system is analogous to an electronic computer and is conceptualised as having inputs, throughputs and outputs. Inputs begin when information in the form of a stimulus (verbal, visual, tactile) impinges on the sensory receptors. As the sensory information moves through the system, it is altered, transformed into a meaningful code, compared to information already in memory and is stored in memory for future use. Output occurs in the form of verbal and non-verbal responses, a decision, or a representation stored in memory.

The information processing framework has several basic characteristics:

- people are viewed as autonomous intentional beings who interact with the external world;
- the mind through which they interact with the world is a general-purpose, symbol processing system;
- symbols are acted on by various processes which manipulate and transform them into other symbols which ultimately relate to things in the external world;
cognitive processes take time, so predictions about reaction times can be made if one assumes that certain processes occur in sequence and/or have some specified complexity;

- the mind is a limited capacity processor having both structural and resource limitations;

- the symbol system depends on a neurological substrate, but is not wholly constrained by it (Eysenck & Keane, 1990, p.9).

A simple information processing model of human performance has been proposed by Romiszowiski (1990).

*Figure 2.1: An information processing model of human performance (Romiszowski, 1990).*

Romiszowiski’s model conceives of the performer as a system interacting with an environment or problem situation. The performer is seen as composed of four principal sub-systems consisting of:

- receptors that perceive and select incoming information for interpretation and action. Usually the senses are employed, but the sub-system also includes reflective-introspection;

- memory or store. Knowledge from prior learning is kept in an organised manner (long term memory);
• processor or brain or intellect-structures. New relationships between incoming and existing information are processed. The processor sets up hypotheses and tests them. Romiszowiski claims that this is where thinking occurs;

• effectors. The learner realises the actions that communicate the results of the memory-recall and information-processing. It can include any of the following: limbs; voice; written communication; introspection and self-analysis.

Many of these ideas originate from the view that human cognition can be understood by comparison to computers (Eysenck & Keane, 1990), but the use of a computer as a metaphor can be taken to extremes and the various models of information processing lie along a continuum. At one extreme of the continuum is the computer simulation approach, which seeks to develop computer programs that will model the human thought processes. At the other end of the continuum are theorists who use the computer metaphor as a convenient heuristic device. If the metaphor is taken too far then we are likely to ignore the very important differences between humans and machines. The machine analogy is misleading, as humans are not passive, motionless entities controlled by external forces. Rather they are viewed as active seekers of information in the environment. They often construct inferences about this information using present knowledge and past experience (Eysenck & Keane, 1990). The following statement summarises the position taken in this study which is that "the assumptions incorporated in the information processing approach may be reasonable as far as they go, but they do not go far enough" (Eysenck & Keane, 1990, p.10).

An alternative approach to human learning is to consider humans as knowledge constructors. That is, humans construct meaning from their present experiences by relating them to past learning experiences.

**A constructivist approach to learning**

A constructivist approach to learning is based upon the supposition that as learners interact with the world, they construct their own experience and knowledge (Lyddon & McLaughlin, 1992; Novak, 1988). Thus, learning is viewed as "the product of self-
organization" (von Glaserfeld, 1989, p.136). This learning process is supported by two broad principles: first, knowledge is not passively received but actively constructed by the learner, and second, learners generate understanding when they relate prior knowledge to present experiences (Wheatley, 1991). Often this occurs when the learner attempts to reconcile differences that exist between his/her explanation and the explanations of others about the same phenomena (Osborne & Wittrock, 1985; Posner, Strike, Hewson, & Gertzog, 1982). Such a process often involves intensive and extensive interpersonal negotiation (Osborne & Wittrock, 1985; von Glaserfeld, 1989).

Piaget's constructivist theory of cognitive development and cognition that involved the notions of assimilation and accommodation was a forerunner of modern day constructivism (von Glaserfeld, 1989). The idea is not new and von Glaserfeld's research showed that unbeknown to Piaget, a forerunner was the philosopher Giambattista Vico (1710). The findings from Piaget's research with children stimulated a rapid growth in research into children's ideas and beliefs before formal learning commenced. Science and Mathematics educators, in particular, became interest in this type of research and it is not surprising that science education was greatly influenced by the ideas of Piaget given the large amount of research that began to emerge at the time.

Researchers in the field of science education have conducted extensive reviews of the research on learner's ideas and beliefs (Osborne & Wittrock, 1985; Driver et al., 1994) and they have consistently found that when learners come to science they already hold some explanatory views of phenomena. These views can be tightly held and can be remarkably unaffected by traditional forms of instruction. Particular views can be quite common and these ideas/beliefs are often remarkably consistent across groups differing in age and nationality.

This section of the literature review focuses on science education because of the long history of research into the nature and importance of the ideas that children bring to the science classroom and the context of this study. Tobin, Tippins and Gallard (1994) state that "although constructivism is not a new way of thinking, it has not been accepted as the prevalent way to conceptualise knowledge by the community of educators." (p.46). They claim that the education community seems to be involved in a process that is similar to what Kuhn (1962) called a paradigm shift. While constructivism may not have been
accepted a decade ago, there are now efforts to understand constructivism across all areas of education. Such a paradigm shift in cognitive theory challenges researchers to develop new techniques for educational inquiry.

Driver (1988) argues that instruction that is based upon a constructivist perspective has to take into account findings relating to learner’s ideas and beliefs and there are various features which may be seen to be characteristic of such a perspective. She stated that:

"a) Learners are not viewed as passive but are seen as purposive and ultimately responsible for their own learning. They bring their prior conceptions to learning situations.

b) Learning is considered to involve an active process on the part of the learner. It involves the construction of meaning and often takes place through interpersonal negotiation.

c) Knowledge is not 'out there' but is personally and socially constructed, its status is problematic. It may be evaluated by the individual in terms of the extent to which it 'fits' with their experience and is coherent with other aspects of their knowledge.

d) Teachers also bring their prior conceptions to learning situations not only in terms of their subject knowledge but also their views of teaching and learning. These can influence their way of interacting in classrooms.

e) Teaching is not the transmission of knowledge but involves the organisation of the situations in the classroom and the design of tasks in a way which promotes scientific learning.

f) The curriculum is not that which is to be learned, but a program of learning tasks, materials and resources from which students construct their knowledge" (Driver, in Fensham, 1988, p.138.)

Furthermore, Driver (1988) stated that this "view of the curriculum also has implications for curriculum development and argues that linear means-ends model of curriculum development is clearly inappropriate as it fails to take account of the purposes and meanings constructed by the various participants. Instead, the progressive development of curriculum requires a reflexive process in which feedback
from all the participants, including researchers, teachers and learners, provides information on how each are interpreting a series of tasks which can then be adapted to improve the extent to which learning is promoted. This implies not only learning by students but also learning by teachers about the ways students construe presented tasks." (Driver, in Fensham, 1988, p.138.).

These principles have been applied to the design, presentation and use of the cognitive tools used by learners in this study.

The impact of increased use of constructivist-based methods with learners includes: increased learner independence; greater learner responsibility and control; increased emphasis upon shared knowledge and decision making, and the development of a coaching and mentoring relationship among teachers and students (Goodrum, Dorsey & Schwen, 1993; von Glaserfeld, 1989). However, such changes in the classroom may not be liked by all students and teachers and concerns about constructivists approaches to learning have been raised by Matthews (1994; 1997). Matthews (1994) argues that constructivism "radically underestimates the degree to which individual cognition and thought is dependent upon social reality, and the sophistication of language available to the individual..."(p.6). This criticism may have been a valid comment about some of the more radical neo-Piagetian based approaches to personal constructivism, but the movement has evolved toward social constructivism which emphasises the social context of the learning situation where learner interaction and cooperative learning are seen as integral parts of the process (Wilson, 1993; Wittrock, 1990; von Glaserfeld, 1989; Vygotsky, 1978). This point has been acknowledged by Matthews in recent articles, but he maintains constructivist learning theory "is simply getting in the way of good teaching" (Matthews, 1997. p.13).

Matthews (1994) also contends that "the vitality of scientific tradition depends upon the success of schools in initiating children into this tradition"(p.13). However, it can be argued that the objectivity of science is not a matter for individual scientists who have been "initiated" into the system, but rather the result of a social process based upon their mutual criticism (Popper, 1976), and such a tradition is supported by modern social constructivism. For the purposes of this study the term 'constructivism' refers to social constructivism which recognises the importance of social interaction in learning. This involves the use of language (von Glaserfeld, 1989), and it is through such a process of
that we "have our experiential reality confirmed by others" (von Glaserfeld, 1989, p.130).

Another major concern is that little consideration has been given to how learners experience constructivist learning (Goodrum, Dorsey & Schwen, 1993). For example, problems arise as the approach places a high cognitive load upon the learner because: the learner is expected to manage their own learning; yet the learning process may not be familiar to the student. Learners often feel less secure as they like to stay with familiar routines and find the reluctance of the instructor to tell exactly what to do in specific situations frustrating. However, researchers such as Collins (1990) have identified trends in school-based instruction with technology which they contend will provide better support for constructivist learning (Cognition & Technology Group, 1991; Wilson, 1993; Tobin et al., 1994). The trends identified by Collins (1990) include: a shift from whole-class to small-group instruction; a shift from lecture and recitation to facilitation and coaching; a shift from working with better students to working with all students; a shift toward more engaged students; an assessment based on products, progress, and effort; a shift from a competitive to a social structure; a shift from all learners learning the same things to different students learning different things; and a shift from verbal thinking to the integration of visual and verbal thinking.

To successfully apply a constructivist approach in the context of this study, the research process must address the issues raised in the previous paragraphs and the role of the instructional designer and the learner needs to be a collaborative one. Such an integrated approach is consistent with a constructivist approach to learning and should improve the usefulness of the cognitive tools produced to help learners read and interpret graphs and tables. As each prototype was developed, it was used with participants, and the purposes and meanings they constructed with the cognitive tools were reflected upon and applied to subsequent revisions of these tools.

As a set of beliefs about knowing and knowledge, constructivism must be able to be used to analyse the learning potential of any situation. Educators should be able to use it as a reflective tool that empowers learners and teachers. Cognitive tools that purport to be constructivist should allow the learner to develop their own knowledge structures and give them the opportunity to interrogate and manipulate the various forms of information
available. Ideally teachers should be able to monitor learner use of cognitive tools so that they can develop an understanding of the way in which their students construct knowledge. This information can be used as a referent for deciding which teacher and learner roles are likely to be more productive in given circumstances, but this does not mean that teachers should focus on monitoring student use of cognitive tools; the reverse is the case as an important role for the teacher is to mediate the learning of students and this implies a strong focus on the learner. To undertake such a role, teachers need to interact with learners to a greater extent, to ascertain what they know and what they are thinking. Cognitive tools may assist learners and teachers in this process as they may help them to develop a clearer understanding of their learning outcomes so that there is congruence between the learning goals of the teacher and the learner (Tobin, Tippins, Gallard, 1994).

Computer-based learning systems have the potential to assist teachers in this task for they can track the way students use an application and this data can be analysed and presented in a form that identifies where instructor mediation is needed. Hence the system could become an ‘infobase’ linked to a support system consisting of expert systems, interactive productivity software, help systems, monitoring assessment and feedback systems (Gery, 1991).

During this study a tracking program was included with the cognitive tools developed. This information was combined with other data and then assessed as a valid information source. The use of this tool to analyse the learning potential of an instructional situation may assist researchers to understand learner performance with cognitive tools as researchers may want to monitor the effects of cognitive tools and to modify them according to the feedback received.

However, systematic, comprehensible and informative data is difficult to gather through the exclusive use of a computer-based learning environment. Much of the data gathered relies on tracking user pathways through applications. These are analysed and plotted as summary maps, but they tell us little about the cognitive processes the learner employed. Instead they are an external manifestation of actions. It is impossible to directly monitor thoughts, but various qualitative techniques such as interviews, video and audio recording can be employed to further our understanding of the cognitive processes
involved in computer-based learning. There is, however, a dilemma as the gathering of so much data can create information overload, making data analysis difficult and time consuming. This can defeat the purpose of the information gathering process. Therefore some rationalisation is necessary either in the amount of data monitored or in the number of subjects involved. The methods need to be efficient in terms of the use of human resources and this study represents an attempt to address these issues.

Vygotsky and the role of language and social interaction

Vygotsky suggests knowledgeable instructors assist learners to construct knowledge that is viable in the community in which they live. Thus the role of these instructor is to facilitate learner by extending the learners zone of proximal development. To achieve this goal, instructors will need to ascertain what learners already know and design tasks so that learners can build upon and verify existing knowledge structures (von Glaserfeld, 1989).

An important aspect of learning that can be overlooked if the model of instruction focuses entirely on the individual student and the teacher is the significant role played by peers in the social setting of learning situations. Many of the ideas associated with early constructivist theory developed from the work of Piaget whose research focus was upon interviews with individual children, but other researchers recognised the role that language played in knowledge construction, especially in social settings such as schools (Vygotsky, 1978; Osborne & Wittrock, 1985). Among other things, the classroom situation is a social situation that involves communication among many participants, language and social interaction are also important factors that impinge upon the way learning occurs.

Vygotsky (1978) claimed that language and other sign systems are culturally constructed and mental development is largely due to contact with social influences. He emphasised the importance of collaboration with peers, teachers and other social actors through the medium of language. Thus language development enables the transformation of behaviour into more abstract realisations.

He defined the zone of proximal development as the zone between the present potential to learn without intervention and the potential to learn with appropriate intervention. The
zone of proximal development is not static and constantly changes over time. An aim of effective instruction is to extend this zone of proximal development in a forward direction. Cognitive tools can provide specific learner support that assists in this process.

Concepts also evolve though social interaction with adults and their peers, and according to the theories developed by Vygotsky (1978) and Bruner (1986): "Children solve practical tasks with the help of their speech, as well as with their eyes and hands" (Vygotsky, 1978, p.26). Language is "...a way of sorting one's thoughts about things" (Bruner, 1986, p.72) and during social interaction, ideas are shared, clarified and affirmed during exchanges with other people. When learners engage in social interactions in classrooms they bring new ideas and prior experiences together, modify their understanding which in turn takes their thinking forward. Thus individuals build on each other's ideas in order to reach solutions. The importance of learner interaction has been emphasised by Woolfolk (1990) who suggests that: "Sometimes the best teacher is another student who just figured out the problem" (Woolfolk, 1990, p.61).

The views of Vygotsky and the many advocates of social constructivism are in accord, as they are based upon the premise that knowledge is constructed through a process that relates new ideas to prior experience which modifies understanding and moves thinking forward. The importance of learner interaction needs to be recognised and in this study was considered to be an essential part of the process of learning with cognitive tools.

**Part 1: Summary**

Part 1 discussed learning theories that are relevant to this study. It focused on cognitive theory and, in particular, the concepts assimilation and accommodation as described by Piaget. These concepts provided the basis for a model of learning which has been refined and extended by researchers who adopted a constructivist approach to learning. As these researchers began to understand more about a constructivist approach to learning, their ideas have evolved, placing more emphasis upon the influence that prior concepts (already possessed by learners) have upon the way new information is assimilated and accommodated into existing schema.

Vygotsky's work with language development emphasised that learning is often a social activity and the social setting in which learning occurs influences the learning process.
Thus in a situation where computers are used to assist learners to assimilate new information it into existing schemata and, where necessary, accommodate their schemata, we need to be aware that there are many variables that remain hidden. Attempts by researchers to control these variables are likely to be disappointing. Therefore, instead of attempting to control variables and follow a so-called 'empirical' research paradigm, researchers may find it more rewarding to recognise that they cannot control all of the variables and instead use a 'naturalistic' research paradigm so that we can develop a more detailed understanding of the learning processes involved in this context.

**Part 2: Learner processing of information in graphs and tables**

The purpose of Part 2 of this chapter is to examine research that describes how learners process and assimilate new information into their schemata. The general principles that emerge from this research are then used to assist in the process of designing of cognitive tools that assist learners to process information presented in the form of graphs and tables. These findings will be applied to the design of the cognitive tools.

**Features of cognitive tools that support learner processing of information**

Cognitive tools "are generalisable tools that can facilitate cognitive processing" (Jonassen, 1992b, p.2). They are both cognitive and computation support devices that guide and extend the thinking processes of the users. Such tools are external to the learner: they are computer-based devices that extend the thinking processes of the learners and are designed to engage the learner in meaningful processing of information. Cognitive tools engage the generative learning process which occurs when learners assign meaning by relating current information to prior knowledge (Wittrock, 1974). This results in deeper information processing because: the learner activates appropriate schemata; uses them to interpret new information; assimilates new information back into the schemata; reorganises them in the light of newly interpreted information; and then uses those revised schemata to explain, interpret, or infer new knowledge.

A cognitive tool such as a concept map creation tool allows students to learn with information processing technologies as opposed to learning of them. Hence, they
facilitate the learner's cognitive processing. They are learner controlled and not teacher or technology driven and are designed to reduce information processing, making a task easier for learners (Jonassen, 1992a, 1996).

Cognitive tools are based upon constructivist epistemology. They augment thinking and facilitate knowledge construction. Therefore, they can be thought of as constructivist tools. As Jonassen (1992a) states "cognitive tools are constructivist because they actively engage the learner in the creation of knowledge that reflects their comprehension and conception of the information rather than focusing on the presentation of objective knowledge" (p.5).

However, it is not reasonable to assume that all knowledge should be personally constructed by learners. Socially constructed reality plays a very important role in all societies and important procedures such as road rules and laws could not operate unless a socially constructed reality existed. Complete idiosyncratic knowledge constructions would result in chaos. Therefore, knowledge should to some degree be personally constructed, but also socially shared.

**Strategies that help learners to process information**

Every moment we are exposed to large amounts of information; however we do not suffer from information overload because we select the information which we regard as important and ignore that which is not. Our memories can only receive, process, store and retrieve a finite amount of information (Clark & Taylor, 1994; Yates & Moursund, 1989; Miller, 1956; Simon, 1974). It is likely, then, that graphs and tables that contain large amounts of information will be difficult to interpret.

Research suggests that the general strategies discussed below assist learners to process information provided in the form of text and graphics. These strategies are described under the headings of:

- linking new information to existing schema;
- helping learners to transfer prior learning to new situations;
- the use of metacognitive strategies;
- strategies that can reduce learner cognitive load;
• catering for differences in the way learners process information.

A conceptual model of human memory may help researchers to visualise and understand how the processes of assimilation and accommodation occur and this model may act as a source of ideas for the design of cognitive tools provided to assist learners in this process.

Figure 2.2 shows a model of how information may flow in short and long-term memory registers (After Gagné, 1987). The model can be seen in terms of a computer information processing metaphor (Gagné, 1987). In particular inputs are stored and processed by three different kinds of memory: short-term memory, working memory and long term memory.

*Figure 2.2: A model of the structure of human memory (after Gagné, 1987)*

Short-term memory receives information coming to the learner through the senses. It stores limited amounts of information for a fairly short time interval. Single items stored in short-term memory die away after about 20 seconds (Peterson, 1959, pp.193-198), and researchers considered the capacity of this form of memory to be seven plus or minus two items (Miller, 1956; Simon, 1974). However, a phenomenon known as 'chunking' makes it possible to store familiar words or letter combinations as meaningful groupings (Simon, 1974; Clark & Taylor, 1994; Gagné, 1987) and this extends the capacity of short term memory.

Working memory compares incoming information with previously stored information (in long-term memory), retrieved to working memory so that it is "matched" and recognised
This kind of memory also combines or integrates new material with an organised set of existing knowledge (schema) retrieved from long-term memory. Another function of working memory is rehearsal which permits initially encoded material to be retained over a longer period of time.

Many researchers claim that humans have two types of long-term memory that assist them in learning: episodic memory and semantic memory, as shown in Figure 2.2 (Tulving & Donaldson, 1984). Episodic memory receives and stores information about time dated episodes or events as well as spatial relations among events, while semantic memory is necessary for the understanding and use of language. It is a mental thesaurus of organised knowledge that a person possesses about words and other verbal symbols, meanings referents and relationships between concepts, terms, and rules. Tulving (1972) perceived these forms of memory as two interdependent information processing systems that selectively receive, retain, retrieve and transmit information. Holley and Dansereau (1984) also saw these forms of memory as interdependent when he discussed the development of spatial learning strategies that rely on episodic memory and semantic memory.

It is assumed that the semantic memory structures of learners process information in accord with hierarchically schemata (Bransford & McCarrell, 1974) and learning is a reorganisation of these knowledge structures (Jonassen, 1988). For example, a schema for an object, event or idea is comprised of a set of attributes such as the associations that an individual forms around an idea (e.g., firetruck such as red, hoses, fireman, siren). Our knowledge structure consists of schemata for all of these attributes, so that schemata are said to embed within each other. Such schemata are viewed as interconnected and overlapping.

Each schema we construct represents a mini-framework on which to interrelate elements or attributes of information about a topic into a single conceptual unit (Norman, Gentler & Steeves, 1976; Lindsay & Norman, 1977). These concepts are all arranged in a network of relationships known as a semantic network. While this theoretical model has been useful in providing a framework for studies of prose processing where the activation of appropriate existing schema facilitates comprehension and recall (Bransford
& McCarrell, 1974), it is not precise enough for accurate prediction in varied education settings.

Because our semantic networks represent our knowledge structures and the schemata in our semantic network are linked together by way of various associations, learners can combine ideas, infer, extrapolate, or otherwise reason from them. Probably the most universally accepted method of modelling semantic networks is the "active structural networks" (Quillian, 1968). Structural networks are composed of nodes (schemata) and ordered, labelled relationships (links) connect them (Norman et al., 1976). These networks describe what the learner knows, providing the foundations for learning new ideas, thus expanding the learner's semantic network. In this view, then, learning consists of building new structures by constructing new nodes and interrelating them with existing nodes and with each other (Norman, 1976). The more links that can be formed between existing knowledge and new knowledge, the better the information will be comprehended, and the easier learning will be. Therefore learning is seen as reorganising the learner's knowledge structure, but such reorganisation is not a random or haphazard event; it is purposive. This view is similar to the Piaget's descriptions of assimilation and accommodation. In Piaget's words, "...no behaviour, even if it is new to the individual, constitutes an absolute beginning. It is always grafted onto previous schemes and therefore amounts to assimilating new elements to already constructed structures" (Piaget, 1976, p.17).

When a student acquires knowledge from an instructor, the newly acquired knowledge is "grafted" onto previously help schemata. Empirical evidence has demonstrated that during this process, the learner's knowledge structure begins to resemble the instructor's (Shaiveson, 1974; Thro, 1978). Thus learning may be conceived as the mapping of the subject matter knowledge (usually that possessed by a teacher or expert) onto the learner's knowledge structure. Von Glaserfeld (1995) asserts that this cognitive change takes place when the learner's existing schema fails to produce an expected result in a given situation and an alteration or accommodation occurs in order to maintain or re-establish equilibrium.
Linking new information to existing schemata

Learners need help to link new information with prior knowledge so that the new knowledge becomes embedded into existing schema (Clarke, 1992; Gery, 1989; Jonassen, 1988; Hannafin, 1989; Kenny, 1993; Bonner, 1988; Holley & Dansereau, 1984). Strategies are needed that assist instructors to probe the cognitive structures of learners, and help them to map their existing knowledge structures. Such strategies should make it easier for instructors to plan learning experiences that help learners to re-organise their knowledge structure in order to assimilate the new information and if necessary accommodate their schemata. Computer-aided learning strategies are possible ways of supporting both instructors and learners in these tasks, and hypertext, in particular, shows promise.

For the purposes of this study "the term hypertext refers to both textual and non-textual systems, single medium and multimedia: no distinction is made between hypertext and hypermedia."(Hammond, 1991, p.150). Computer software that is hypertext-based makes use of the node and link model to create a learning environment that is similar to the way that human memory is organised (Nelson, 1981). Price (1991) proposed that such learning environments should assist learners to form nodes and links that match their own semantic network. He described these "associative links" as basic cognitive processes that allow the human brain to store and retrieve information quickly and intuitively.

The strategies for learner information processing that follow suggest ways that learning can be organised to enhance "associative links" or semantic memory. These models consider depth of processing (including top-down/ bottom-up processing) and reorganisation of the stimulus material presented. They have been applied to text and diagrams, but there may be some transfer of these strategies to graphs and tables.

Depth of processing

Craik and Lockhart (1972) suggest that there are two levels of information processing, surface processing associated with the physical characteristics of the stimulus (eg. brightness, lines, angles) and deeper processing which is concerned with the semantic aspects of the stimulus. They suggest that the durability of memory depends on the level
of processing. However their model has been criticised as an oversimplification, with dispute over the criteria used to distinguish the two levels of information processing (Holley & Dansereau, 1984).

Another approach is to use what is known as top-down and bottom-up processing. The effect of top-down information processing is to engage the learner and create expectations about the material to be presented. It is claimed that learning is enhanced when the learner is provided with an advanced organiser and an overview of the stimulus material to be presented can be considered as one example (Ausubel, 1960; Ausubel & Youseff, 1963; Clarke, 1991; Kenny, 1993; Mayer et al., 1984; Mayer, 1980, 1976, 1975).

Bottom-up information processing assumes that the learning of new information is affected by the properties of the stimulus material presented. The learner will attempt to reorganise the information presented into a form that can be assimilated by his/her existing schemata.

Both models have been applied to learning strategies that enhance the processing of information from text (Lindsay & Norman, 1977; Rigney & Munro, 1977; Rumelhart, 1977). However, the research findings are not conclusive and these models may be oversimplifications as a dialectic exists between these types of information processing (Holley & Dansereau, 1984; Kolb, 1984; Salomon & Perkins, 1989). Another reason may be that the two types of information processing are merely subsets of a more general strategy.

**Reorganisation of information into spatial networks**

Holley and Dansereau (1984) claim that "if network representations are the most adequate model of human knowledge available, then presenting information in the form of a network will be the most adequate parallel to the knowledge presented in the text." (p.25). Jonassen (1996) argues that it is the process of network construction rather than the final representation that benefits learners most of all as it requires learners to identify important concepts in a content domain, to link them, and to articulate these links. While it is not an easy process for novices, he claims that this process "mirrors to some degree the natural pattern of knowledge acquisition" (p.98).
Research associated with printed text and verbal materials demonstrated that an organised presentation produces better recall than an unorganised one (Holley & Dansereau, 1984). However, in the absence of organisation, subjects will attempt to create their own organisation (Bower, 1972). Part of this study will try to ascertain if learners make use of a variety of cognitive tools when they create organisation structures that reflect their understanding of information presented in text, graphs and tables.

Spatial networks can be created in a variety of ways that have been described as abstract representational schemes (Holley & Dansereau, 1984). Abstract representational schemes can be content dependent (eg graphs, flow charts that relate to specific content) or content independent (eg matrixing, networking, concept mapping). These representational schemes cannot be applied universally with equal success as they tend to be context specific. Three general strategies were identified by Holley and Dansereau (1984) and these were: networking, mapping, and schematising. Spatial learning theory (Holley & Dansereau, 1984), discussed at the end of this section, represents an attempt to integrate these strategies into a learning theory about cognitive processing of text-based information.

Hyerle (1996) describes three types of visual tools which he calls brainstorm webs, task-specific organisers and thinking process maps. These tools appear to perform functions similar to those referred to as abstract representational schemes and table 2.1 shows how Heryle's classification relates to that of Holley and Dansereau.

*Table 2.1: A classification of visual tools by Hyerle (1996).*

The strategies that learners use to form spatial networks are interactive and serve as primary support strategies which operate directly on the text or visual material
(comprehension and memory strategies). Secondary support strategies maintain a suitable cognitive climate and examples are concentration and motivation strategies (Holley & Dansereau, 1984).

The key feature of these primary support strategies are their use of spatial or graphic properties and nodes to represent concepts and lines, or arcs to represent relationships between concepts. Whilst a variety of strategies have been proposed, they have common features which involve the use of a set of related conventions or symbols to label concept(s). The strategy employed during this study was concept mapping.

**Concept maps**

The term "concept map" has been used by many authors to include the types of maps previously described (Fisher et al., May 1990; Margulies, 1991; Novak & Gowin, 1984; Heimlich & Pittelman, 1986; Clarke, 1991; Harlen et al., 1990; White & Gunstone, 1992; Tobin et al., 1994).

In the context of this study concepts represent "anything that can be recognised, that is, that can be attributed identity" (Holley & Dansereau, 1984, p.23). Thus ideas, objects, images, notions, conceptions, beliefs, events, features, properties, and states are examples of concepts. What is commonly referred to as "having a concept" involves the performance of a combination of generalisation and discrimination behaviour such as classifying correctly any examples of the concept and not including any non-examples, however similar they may be.

Often children and adults will revert to concrete examples in order to clarify new concepts. During acquisition learners identify important concepts/ideas in the material and represent their interrelationships and structure in the form of a network map (Armbruster, 1979; Goetz & Armbruster, 1980; Holley & Dansereau, 1984; White & Gunstone, 1992). The result is a structured two dimensional map representing the spatial organisation of the original text. White and Gunstone (1992) claim that the writing of links is crucial (p.18) and that without links the concept mapping technique is of little value. Jonassen (1996) and Hyerle (1996) also agree with White and Gunstone's claim and agree with the view that learners should be encouraged to add paraphrasing and diagrams to the maps they construct (Holley & Dansereau, 1984). However, White and
Gunstone (1992) claim that students find this "the most irksome task ... and would skip it if they could" (p.18). Jonassen (1996) provides a possible explanation for this when he suggests that the process of articulation of links "requires learners to search through the range of possible relationships in order to define the relationship that exists in the context..." (p.98). It is the cognitive challenge of the task that may explain why students find it "irksome".

Therefore it is important that the instructor models the process of concept map creation to students, and provides assistance that can be in the form of named links, structured hierarchies, chains, or clusters of concepts. In particular the instructor needs to model and articulate his/her thought processes as the links are described. Researchers suggests that a period of direct instruction is necessary before learners can successfully employ this process (Harlen, 1992; Hyerle, 1996; Jonassen, 1996; White & Gunstone, 1992). For adult learners they recommend one to two hours of initial instruction. White and Gunstone (1992) recommend the following six steps when concept maps are introduced to learners (p.29):

1. begin with a simple topic, familiar to students so that it is easier for them to concentrate on (or become engaged in) the learning process. Ensure that a small number of terms are involved;

2. model the construction of a concept map to the class. This can be done with an overhead projector or computer with projection facilities;

3. encourage students to think of all possible links and to write down the nature of each link;

4. it is unlikely that students will produce good maps on their first attempt - their first attempt will be an approximation. Provide constructive criticism;

5. you may provide a suggested layout the first time, but it is important to remove these prompts from subsequent maps and allow the learner to take responsibility for the maps they produce;

6. help students that there is not single correct answer to the task.
Similar suggestions are made by Novak & Gowin (1984), Harlen, Macro, Schilling, Malvern and Reed. (1990), and Hyerle (1996). White and Gunstone (1992) also suggest that "there are several discrete steps that students should go through in producing a concept map" (p.16) and they have summarised this as a procedure. They recommend that students need to manipulate the position of concepts in a two dimensional space. Students also need to establish links between concepts that can be easily changed. Hence a set of cards is recommended for use as concept labels and pieces of string for the links. These are arranged on a large sheet of cardboard and then attached with sticky tape. The relation between concepts is then written next to the links. Computer technology can be used to replace cardboard and string as concepts and links can be easily manipulated on a computer screen. Furthermore, the final printed product fits on to one or two pages.

**Instructing learners to construct concept maps**

The model presented in figure 2.3 (Cambourne, 1988, p.33) is a theoretical model that suggests how we could instruct learners to construct concept maps. Several other models also apply but this one was chosen because: it is a holistic model; it includes many of the strategies already mentioned; and it recognises the importance of learner-to-learner and learner-to-instructor interaction in the process.

While Cambourne applied the model to text literacy, his model is applicable in the context of this study because the construction of concept maps relating to text, tables and graphs involves text and graphic literacy. Cambourne uses the terms immersion, demonstration, expectation, responsibility, employment, approximation, to describe the key components of his model. These components are not necessarily sequential and learners may move back and forth as the situation demands, and a later version (Cambourne, 1995) shown in figure 2.4 tries to capture this notion and to make the model broader, deeper and more inclusive.
Brian Cambourne's model of learning applied to text and graphic literacy

Figure 2.3: A holistic model of learning (after Cambourne, 1988).

- Immersion: must be accompanied by engagement.
  - Engagement: occurs when the learner is convinced that:
    1. I am a potential performer of the demonstration.
    2. Engaging with the demonstrations will further the purposes of my life.
    3. I can engage and try to emulate without fear of physical or psychological hurt if my attempt is not fully correct.

- Expectation: *
  - Help learners to make these decisions constitute the 'artistic' dimension of teaching.

- Responsibility: *
  - Probability of Engagement is increased if these conditions are optimally present.

- Employment: *

- Approximation: *

- Response: *

- Demonstration: expectations from those to learners are bonded are powerful coercers of behaviour. We achieve what we expect to achieve; we fail if we expect to fail.

- Learners need to make their own decisions about when, how and what 'bits' to learn in any learning task.

- Learners need time and opportunity to use, employ, and practise their developing control in functional, realistic, non-artificial ways.

- Learners must be free to approximate the desired model 'mistakes' are essential for learning to occur.

- Learners must receive feedback from exchanges with more knowledgeable others. Responses must be relevant, appropriate, timely, readily available, non-threatening, with no strings attached.
The key concept in Camboure's model is that of engagement. He maintains that learners become engaged in their learning when they are convinced that they can perform a demonstrated task and that this task has relevance in their life. Learners need to feel that if they take risks in learning a new skill they will not suffer any adverse physical or psychological consequences.

**Immersion.** The term immersion is used in the model to describe the exposure to language that learners receive in their young life. Camboure (1988) points out that what the learner is immersed in should be "whole, usually meaningful and in a context which makes sense or from which sense can be construed" (p.34). It follows that, if this model is adopted, graphs and tables also should be presented as a meaningful whole rather than as isolated entities. Unfortunately, the graphs and tables found in many texts are not explicitly linked to the text and they are not easy to interpret (Janvier, 1978; Preece, 1985). Thus the graphs and tables are seen as an adjunct to rather than part of the whole presentation.
Two approaches can be taken to make graphs and tables more accessible to learners, one is to improve the way they are presented in text in order to make it easier for the learner to link it to the context, and Chandler and Sweller's (1991, 1994) research about cognitive load theory makes suggestions about how such information can be structured to reduce cognitive load so that the assimilation into the learner's schema is more efficient. The other approach is to provide the learner with a cognitive tool that assists them to integrate the information provided in the graphs and tables into a meaningful whole. During this study concept mapping was employed as a strategy to help learners integrate information presented as text, graphs and tables. The process of concept map construction should encourage learners to process information presented in graphs and tables and then make links with the associated text. This strategy may encourage the learner to become immersed in the total meaning of the information, rather than in discrete parts of it.

**Demonstration.** Cambourne (1988, p. 34) describes two forms of demonstration, actions or artefacts, and he believes that "demonstrations are the raw material of nearly all learning, not only in language". This view concurs with those presented previously, but Cambourne adds the caveat that before learning can occur, a process called 'engagement' is needed (Smith, 1981). While all learners are exposed to thousands of demonstrations each day, most just wash over them and are ignored. Learning only occurs when engagement occurs and Cambourne (1988) claims that this happens when the following criteria are met:

1. the potential learners see the demonstration as achievable and themselves as being able to do it;

2. the demonstration witnessed will somehow serve some future purpose in their lives;

3. when they attempt the demonstration there will not be any unpleasant consequences.

It can be seen that there is a parallel between Cambourne's ideas about engagement and the suggestions by White and Gunstone (1992) about how to introduce concept maps to learners.
Expectation. "Expectations are subtle and powerful coerses of behaviour", (Cambourne, 1988, p.35). They can be viewed from a number of different perspectives. In one sense they can refer to the expectations that the learner has about himself as a learner or they can refer to what 'significant others' convey to the learner. Smith (1981) argues that young learners in particular believe that they are capable of learning anything until they are convinced otherwise. Thus expectation can work for or against learning. In the context of this study the learners need to have an expectation that the concept mapping procedure would help them to interpret text, graphs and tables, and that it had application in a variety of contexts that are meaningful to their lives. During this study the researcher provided a period of direct instruction and demonstration of concept mapping strategies which were designed to provide learners with an expectation that they were capable of using the cognitive tools.

Also the early instructional experience was planned around the task of planning a unit of instruction in science that would be taught to a class later in the year. It was anticipated that this task would be seen as relevant to the preservice teachers involved and the process would be viewed as one that would support their skills in the planning of instruction. Furthermore, a study reported by Roth (1994), found that experience with the process of planning instruction helped teachers to develop more open-ended enquiry techniques in science.

Responsibility. The responsibility for supplying demonstrations and for providing the climate for demonstration lies with the instructor. However, learner responsibility also has two levels: firstly, (s)he is expected to become proficient in the total task; and secondly, (s)he is expected to make the decisions about the most useful aspect with which to engage from the current demonstration. Cambourne (1988) believes that once we take this responsibility away from the learner, and attempt to predetermine the learning process, we complicate the learning process and fragment it.

When teaching students to construct concept maps, White and Gunstone (1992) suggest that teachers provide a demonstration of a possible layout the first time. In subsequent lessons they should remove these prompts and help students to realise that there is not a single correct answer to the task. This approach is supported by Cambourne's (1988)
descriptions of how to approach demonstrations to learners and to develop learner responsibility for their subsequent use of these demonstrations.

**Employment.** Learners need time and opportunity to use, employ and practise in a non-artificial way. They need to have time and opportunity to work with others as well as time alone to use what they have been learning. When instructing learners to construct concept maps it is important to recognise that learners will need time to work with peers and to work alone. Researchers such as White and Gunstone (1992) and Harlen (1992) mention the need for this to occur when learners are instructed in the construction of concept maps.

**Approximation and feedback.** It is claimed by Cambourne that the willingness to accept approximations "is absolutely essential to the processes which accompany language learning" (p.38). When he models "learning to mean" procedures he claims that a cycle of hypothesise, test, modify hypothesis and test again occurs. Such a cycle occurs in many learning situations and can be applied to the teaching of the construction of concept maps. As learners need time to use and re-use a newly developed skill, it is necessary to provide ample opportunity to practise new skills. During this phase of 'use', learners need to receive feedback about their performance. Cambourne (1988) prefers to call this 'response' as he feels that the term 'feedback' has behavioural and mechanistic overtones. Such an approach is also recommend by White and Gunstone (1992) when they discuss teaching children to construct concept maps.

During this study Cambourne's model of learning guided the strategies employed when learners are instructed to create concept maps with a concept mapping tool. These strategies arise from the "principles of engagement" displayed in figure 2.3 (Cambourne, 1995). He discovered that when these principles are consciously employed by instructors, the probability of increased learner engagement with demonstrations dramatically increased. In Piagetian terms these principles can be thought of as providing optimal conditions for learner assimilation of new information or the learner is able to engage "in goal-directed action" (von Glaserfeld, 1995).

Cambourne uses the terms transformation, discussion and reflection, and application which together describe in Piagetian terms the processes involved in accommodation. He
believes that all of these processes are interwoven and interact with each other. However, we need to be aware of what these processes are in order to provide optimal conditions for learner accommodation. Transformation is the part of this process that occurs when learners take something demonstrated by another and make it part of their own understanding and/or skills. For example, a learner may express some knowledge or concept in their own words while closely approximating the core meaning. Cambourne’s research suggests that the process of transformation is enhanced through discussion with others, and older learners, like younger counterparts, "need a myriad of opportunities to interact with others in order to clarify, extend, refocus, and modify their own learning" (Cambourne, 1995, p.188). He asserts that "learning, thinking, knowing and understanding are significantly enhanced when one is provided with opportunities for 'talking one's way to meaning,' both with others and with oneself" (p.188).

Application involves problem solving and Cambourne suggests that there is a multilayered relationship among application, discussion/reflection and transformation when two or more persons are collaborating in solving a problem. This involves discussion and transformation often occurs as a consequence of discussion. Such a process of transformation leads to the construction of new understanding or knowledge, or the mastery of new skills. Finally, the new knowledge can be reflected upon and further transformed. Such linguistic interactions are described by Piaget as the most frequent cause of accommodation (von Glaserfeld, 1995, p.66).

**Applying spatial learning theory.** Spatial learning theory advocates a strategy that breaks up the process of comprehending text and diagrams into small manageable parts that focus on processing of specific features (eg. labels, diagrams, text). It then focuses on improving specific learner skills associated with these parts. Then the learner re-combines the information into a semantic network, summary or concept map. Whilst the strategy cannot make up for lack of essential knowledge, advocates claim that it does allow the learner to make more efficient use of his/her current knowledge (Holley & Dansereau, 1984). Six steps that constitute the strategy are:

- select key concepts. This is a recognition process that activates relevant knowledge, and assists in topic identification;
write the key concepts;
make an attribute list of the key concepts;
relate key concepts in a spatial relationship;
rearrange spatial representations;
compare representation to the text.

There is a similarity between these steps and those recommended by White and Gunstone (1992). In this study the first five steps recommended by Holley and Dansereau (1984) were combined with those recommended by White and Gunstone (1992) to guide the design of the concept tools. The cognitive tool developed consisted of the six elements shown in Figure 2.5.

*Figure 2.5: The design of the concept mapping tool*

The six buttons on this palette will have the following functions:

- *concept* allows the user to type concept labels and to move these labels in two dimensional space;
- *link* allows the user to draw link arrows between concepts. Arrows indicate the direction of these links;
- *note* allows the user to attach explanatory notes to the links or concept labels;
- *eraser* allows the user to correct mistakes;
- *help* provides access to a simple help screen;
- *print* allows the user to print out the concept map and the notes.
Uses of concept maps. Six uses have been identified by White and Gunstone (1992) and these are:

- to explore understanding of a limited aspect of the topic;
- to check whether learners understand the purpose of instruction;
- to see whether learners can make links between concepts;
- to identify changes that learners make in relationships between concepts;
- to find out which concepts are regarded as key ones;
- to promote learner discussion.

Jonassen (1996) expresses these ideas in a different way when he asserts that "the process of creating semantic networks engages learners in an analysis of their own knowledge structures, which helps them to integrate new knowledge with what they already know" (p.95).

In this study the purpose of the computer-based concept mapping tool will be similar to those proposed by Jonassen (1996, p.95). He proposed that such tools could be used by learners to: reorganise knowledge; explicitly describe concepts and their interrelationships; encourage deeper processing of knowledge; relate new concepts to existing concepts, and spatially represent concepts that summarise the topic they are studying.

Mapping does have limitations and there has been dispute over the long-term benefits of this strategy (Armbruster, 1979). White and Gunstone (1992) claim that mapping appears to be best suited for probing understanding of a whole discipline or a substantial part of it. However Armbruster (1979) claims that mapping is limited in its application as it doesn't give a "big picture" of a domain of knowledge. Advocates such as Heillich and Pittelman (1986) assert that it is a very good device to use to find out how learners link ideas, or how they see the structure of a large topic. Others argue that while concept mapping is a useful tool, it is still just another strategy, and even strong advocates of concept mapping concede that if it is over-used, it becomes less effective (White & Gunstone, 1992).
One assumption made is that concept maps are reasonable representations of cognitive structure (Holley & Dansereau, 1984). In a study that compared pattern notes to free word association structures Jonassen (1987) found that the underlying structures in concept maps were virtually identical to those in the free association tasks. However, they are not true maps of a learner's knowledge structure; instead they are a representation of the learner's knowledge structure (Jonassen, 1996). Furthermore the propositional networks that exist in the mind are likely to be far more complex (multidimensional) than can be represented by a concept map.

Another assumption is that the process of creating a concept map engages learners in an analysis of their own knowledge structures and this will help them to use knowledge more frequently. Jonassen (1992a) argues that the process of concept map construction aids learning by requiring learners to analyse the underlying structure of the ideas they are studying. In other words organised information is more memorable. Like White (1992), Jonassen (1992a) believes that "if semantic networking is to be maximally effective, learners need to interpret the clusters and dimensions of their map as well as build them" (p.20).

It is difficult to use concept maps to clearly represent causal relationships without attaching explanatory notes. Such a feature was added to the concept mapping tool used during this study because it was anticipated that such a feature may make it easier for learners to explain causal relationships.

Critics of concept mapping claim that it describes only declarative knowledge and therefore can only benefit memory processing, but research by Gordon and Gill (1989) has shown the central role of these knowledge structures in problem solving. Others such as Jonassen (1996) and Diekhoff (1983) share this view and they argue that concept maps represent an intermediate type of knowledge which has been called structural knowledge. Structural knowledge is knowledge of how the ideas within a domain are integrated and interrelated (Diekhoff, 1983), and this knowledge aids the articulation of both declarative and procedural knowledge.
Additional strategies that help learners to process information

Research related to spatial strategies in processing and remembering text showed that students learn and remember more from text when they employ one or more of the following strategies:

- study the text in a deep and meaningful fashion;
- form mental images;
- construct an organised interrelated representation of concepts;
- bring to bear appropriate knowledge and incorporate the new information with what they know;
- process the material initially in a manner compatible with testing conditions;

These steps focus on development of learner skills in processing text or graphics, but an equally important strategy is to design the instructional material so that it is easier for the learner to process. Whilst the learner is the focus, it needs to be acknowledged that focusing on the learner alone only looks at part of the learning process. The organisation and delivery of the information also needs to be considered as this can enhance cognitive links that promote the transfer of prior learner knowledge to a new situation. Cognitive tools have the potential to assist learners in the transfer of prior learning to new situations.

Helping learners to transfer prior learning to new situations

Salomon and Perkins (1989) define learning as something that leads to a later performance which we identify as more or less the same, whereas transfer is more likely to be mentioned when learning has a side effect that we were not perfectly confident that it would have (p.116.). There are plenty of research data to suggest that learners need
help to transfer prior knowledge to the context of a problem with which they are currently

Salomon and Perkins (1989) argue that transfer of learning is not a unitary phenomenon
and that there are alternative transfer paths and many different sets of conditions. This,
they believe, would explain why research results are likely to vary. Their research
suggests that transfer may be enhanced when learners are provided with a variety of
pathways to follow. Since cognitive tools are capable of providing learners with a variety
of learning pathways, they may enhance transfer.

Low-road transfers (Salomon & Perkins, 1989) occur when a performance is
unintentional, implicit, based on modelling, and driven by reinforcement. They define
the "amount of transfer" as how much improvement occurs and the "distance of transfer"
refers to how closely the tasks are related. Their research suggests that low-road transfer
affects the amount of transfer but has a much smaller effect on the distance of transfer.
The mechanism for low-road transfer is practice with related tasks which leads to
automation. Drill and practice software is an example of a computer-based learning that
relies on low-road transfer.

High-road transfer involves a greater distance of transfer because knowledge and skills
are abstracted from their present context and reapplied in a new context. This form of
transfer relies on the mechanisms of abstraction and mindfulness. Abstraction is a
process that involves a variety of information processing manoeuvres, whilst
mindfulness is the volitional, metacognitively guided employment of non-automatic
processes, typical of deeper processing, and conscious manipulation of the elements of
one's environment. Such a process is more difficult to achieve through instruction and it
is not surprising that the researchers are interested in improving this form of transfer
through metacognition.

Computer-based applications which support transfer through deeper processing and
conscious manipulation of information have been called mindtools (Jonassen, 1996). Also
some have been called visual tools (Hyerle, 1996). Mindtools are "computer
applications that require students to think in meaningful ways in order to use the
application to represent what they know" (Jonassen, 1996, p.3) and include databases, spreadsheets, semantic networking tools, expert systems and computer-mediated communication systems. Visual tools are tools that Jonassen calls "semantic networking tools" and can be considered a subset of mindtools.

**The use of metacognitive strategies**

Jo (1993) describes metacognition as "... cognitions about cognitions or the executive decision making process in which the individual must carry out cognitive operations and oversee his/her progress" (p.416). Figure 2.6 represents the components of metacognition commonly agreed upon by most researchers.

*Figure 2.6: Components of metacognition*

![Diagram of metacognition components]

Flavell (1987) suggests that metacognitive knowledge can be divided into three categories: knowledge of person variables; task and strategy variables; and regulation.

Person variables refer to the kind of knowledge and beliefs that concern what humans are like as cognitive beings (affective, motivational, perceptual); a learner may believe that (s)he is good at dealing with numerical information, but poor at verbal tasks. Task variables relate to how the nature of the information encountered affects and constrains the ways learners to deal with it. For example, a learner will have to take more time to process densely packed information. Strategy variables are used to achieve more than just to reach the cognitive goal or subgoal; a learner may employ a cognitive strategy to compare a series of numbers displayed on a computer screen, but a metacognitive strategy would be to use a sorting tool to rearrange the numbers so that the task was
easier to perform. Thus metacognitive strategies are self-regulated, conscious experiences that are cognitive and affective; any kind of conscious affective or cognitive experience that is pertinent to the conduct of intellectual life is a metacognitive experience. Person, task and strategy variables interact and we need to understand these interactions (Flavell, 1987). Furthermore, personal growth in metacognitive strategies is often related to an ongoing experience and it needs to be recognised that learners need time and experience to better regulate their cognitive processes (Flavell, 1987).

Many studies have reinforced the notion that learners can control and direct their mental processes if they are provided with cognitive and metacognitive support (Flavell, 1987; Flavell, 1976; Li, 1993; Holley & Dansereau, 1984; Jo, 1993). During information processing metacognitive guidance plays a major role, a process during which Salomon and Perkins, (1989) claim that "mindful abstraction" occurs: metacognitively guided and effortful abstraction of information. Cognitive tools can support this process; "mindful abstraction" and concept mapping tools are one example. Moreover, findings from metacognition research suggest that the development of skills in metacognition will not only help learners to process information, but to transfer these strategies to new situations (Salomon & Perkins, 1989).

Strategies that can reduce learner cognitive load

In any learning situation, whether computer-managed or human-managed, cognitive overload is likely to occur when the total cognitive demand of the task is beyond the learner's current ability to process the available information. It is important, therefore, that learning or the environment be structured to reduce this effect. Active self-regulation and purposeful control are needed to keep metacognition active during the learning process, but unsupported learners usually cannot meet these demands and suffer cognitive overload. Thus, ways to reduce cognitive load associated with the application of metacognition to information processing need to be explored.

Clark and Taylor (1994) suggest eight ways to avoid cognitive overload in learning situations. They suggest that instructors should:

- talk less and incorporate the key learning points into succinct reference notes;
- do less while your learners do more;
• chunk instructional segments and distribute them evenly over the time available;

• design the layout of workbook pages and on-screen computer presentations to aid memory;

• design job aids be used as aids to memory during and after training;

• include some drill and practice exercises to achieve automation;

• support the learner through the provision of "training wheels" that can be removed when (s)he is capable or achieving the task without support;

• build in strategies that allow the instructor to detect and remedy cognitive overload during training sessions.

Since most of these suggestions are generalisable, they can be applied in the context of this study. In particular the strategies of the even spacing of presentations of chunks of information over time, the provision of succinct printed instructions (help screens), and the provision of removable support were applicable to this study.

Another source of cognitive load relates to hypertext learning environments such as the one developed during this study. The term 'hypertext' was coined by Nelson (1981) to describe a combination of natural language text with the computer's capacity for interactive branching, that created a dynamic display of non-linear text which cannot be printed conveniently on a conventional page. Hypertext software allows users to explore information in a non-linear and interactive fashion (Barker & Tucker, 1990). The learning environments created by hypertext software give the learner access, via computer, to graphics, sound, text, video, animation and other learners. The learner can be free to follow his/ her own non-linear path through this environment (Nelson, 1981), but without navigational support it is very easy for a learner to become 'lost in hyperspace' and to be unsure about what information they have covered and how it links together (Sewell, 1990; Hammond, 1991).

Jo, (1993), Hedberg and Harper, (1991) and Doland, (1989) assert that cognitive overload in hypertext learning environments is related to the degree of complexity of the non-linear learning environment. Variables such as number of choices, task scheduling,
tracking guides and navigation aids overload learner short-term and working memories (Jonassen, 1988). Therefore, it is not surprising that researchers propose that hypertext learning environments need careful management of the number of user choices in order to make decision making easier and reduce cognitive load (Liebhold, 1987; Doland, 1989).

Findings from research into learner use of hypertext systems by various researchers revealed a number of problems which can occur (Allinson & Hammond, 1990; Jones, 1987; Ferry, Hedberg & Harper, 1996). First, learners often get lost. The knowledge base may be large and unfamiliar, the links provided will not be suitable for all individuals and for all tasks, and the users may be confused by the embarrassment of choice. Second, learners may find it difficult to gain an overview of the material. They may fail to see how parts of the knowledge base are related and may even miss large relevant sections. Third, even if learners know specific information is present, they may have difficulty finding it. A related problem is that of uncertain commitment where the user is unsure where a link will lead or what type of information will be shown. A fourth problem arises where minimal guidance or constraints are provided as learners are liable to ramble through the knowledge base in an instructionally inefficient fashion with their choices motivated by moment-to-moment aspects of the display which attract attention. Thus a system which gives a multiplicity of choice but the minimum of guidance may not be ideal. The term navigation has been used to describe most of these problems, and the section following describes ways that navigation may be managed in a hypertext environment.

**Reducing cognitive load in hypertext learning environments**

The less structured a hypertext learning environment is, the more likely learners are to experience navigation problems (Hammond, 1991). Without an explicit external organisation, learners find it difficult to integrate what they have learnt into their existing schemata (Conklin, 1987; Hedberg, 1988; Hedberg & Harper, 1991; Doland, 1989; Hammond & Allinson, 1991; Underwood, 1988; Tripp & Roby, 1990; Jonassen, 1988). Stanton and Baber (1992) discusses the effect of navigation upon planning of search strategies which are sometimes referred to as cognitive strategies.
Webb (1990) suggests that maps and analogies assist navigation. He found that performance with the assistance of analogy was superior and supported goal-directed movement through information. Four elements of successful cognitive maps were identified: where you are; where you want to be; how to get there, and how to overcome obstacles. Webb also suggests that users of hypertext may wish to create their own spatial cognitive map. His suggestion looks at the problem of learner use of hypertext from the perspective of the learner rather than that of the instructional designer.

When we assist learners to integrate new information from hypertext into their own knowledge structures we need to be aware that the willingness and ability of learners to use their own knowledge structures to assimilate information is dependent on individual differences such as cognitive ability and learning styles (Hammond, 1991). Researchers have argued that we need to find out how to structure hypertext to replicate content structures or knowledge structures of learners, and how likely are users to assimilate these structures or accommodate to them (Dede, 1990; Barker & Tucker, 1990; Jonassen, 1988; Underwood, 1988). For too long authors of instructional software have been plagued with problems such as: where should users begin in a hypertext learning environment; what sort of access structures are needed to guide the user; and how overt should navigation aids be (Hammond, 1991). The focus has been upon designing the hypertext environment to match the ways learners will want to use the materials. This could be related to the degree to which the individual is familiar with the environment, time available, amount of self-direction the individual is motivated to assert, together with the amount of change occurring in the environment. Because these variables interact, it is not possible to cater for more than a few sets of circumstances. Jonassen (1992b) argues that "rather than develop more powerful teaching hardware, we should teach learners how to think more efficiently" (p.2). One way of achieving this goal is to develop cognitive tools that assist learners to process and structure information and mindtools (Jonassen, 1996) and visual tools (Hyerle, 1996) are examples.

Besides navigation, other sources of cognitive load exist. For example, the demands associated with cognitive processing of information in numerical form have the potential to create cognitive overload, but cognitive tools such as calculators can help to reduce this (Doland, 1989; Hammond & Allinson, ; Conklin, 1987; Webb & Kramer, 1990; Shuell,
We need to explore the use of other cognitive tools and part of this study is a contribution to this field of research.

Sweller (1994) suggests that to reduce cognitive load, instructional designers need to focus learner cognitive activity on schema acquisition which is a gradual and incremental rather than an all-or-none process. When a complex intellectual skill is first acquired, it may be useable only by devoting considerable cognitive effort to the process. With time and practice, the skill may become automatic to the point where it may require minimal thought for its operation. Then the intellectual performance can attain its full potential. However, instructional techniques that are not directed at schema acquisition and automation "frequently assume processing capacity greater than our limits and so are likely to be defective" (Sweller, 1994, p.298).

Sweller (1994) proposed two general sources of cognitive load that can affect instruction. He calls these extraneous and intrinsic sources of cognitive load (p.303). Extraneous sources are artificial because they are imposed by the instructional methods, but intrinsic sources are not controlled by the instructor. Sweller asserts that the primary determinant of intrinsic cognitive load is element interactivity. The higher the number of interacting elements (information that the learner needs to understand in order to successfully complete a task), the greater the cognitive load generated. Schemata organise these elements and, in turn, can act as elements themselves in higher order schemata. That is, once a schema is acquired and automated, it can act as an element in further tasks.

For any given instructional situation intrinsic cognitive load is fixed and cannot be reduced, but extraneous cognitive load can be reduced. Extraneous cognitive load may be less important when the intrinsic cognitive load is low. However when intrinsic cognitive load is high, the reverse is true, and when learners deal with high element interactivity materials, the combination of high extraneous and intrinsic cognitive load may overwhelm their limited processing capacity. This may be the case when learners attempt to interpret a combination of text, graphs and tables found in many text books.

Cognitive load theory suggests that effective instructional material directs cognitive resources toward activities that are relevant to learning. It is concerned with the manner
Researchers in the field claim that many learning procedures engage students in cognitive activities far removed from the ostensible goals of the task and the cognitive load generated by these irrelevant activities can impede skill acquisition (Chandler & Sweller, 1999, p.294). For example, mental integration of information in graphs, tables and diagrams in text requires searching for appropriate referents in the graphs, tables and diagrams or in a set of statements. This can split learner attention and create additional cognitive load. If the materials are redesigned to reduce the amount of split attention, then cognitive load is reduced and this makes the task of mental integration is easier.

The cognitive tools developed during this study will have a positive impact upon the cognitive load experienced by the learners and this may relate to the way in which they are used. In particular, learners may have preferences for tools that help them to reduce cognitive load as they process information. Also the tools that learners prefer to use may relate to differences in the way learners process information and this issue is discussed in the next section.

**Catering for differences in the way learners process information**

An established history of research suggests that learning styles influence the ways in which learners process information (Dunn et al., 1982; Kolb, 1984; Claxton & Hurrell, 1987; De Bello, 1990; Dunn et al., 1989; Jung. W., 1993; Jonassen & Grabowiski, 1993; Schmeck, 1988; Sims & Sims, 1995). Since most learners have preferred ways of learning, researchers claim that different cognitive (learning) styles require different modes of learning (Romiszowski, 1990; Tyler, 1993; Allinson & Hammond, 1990; Stanton & Baber, 1992; Jonassen & Grabowiski, 1993). Similarly, Messick describes cognitive styles as "characteristic self-consistencies in information processing that develop in congenial ways around underlying personality trends" (Messick, 1984, p.23). For the purposes of this study the terms learning style and cognitive style are used as synonyms.

While various systems of learning styles have been proposed, there are three popular categories. Curry's (1987) extensive study of 21 learning style instruments from North America, Europe and Australia suggests that it is possible to reorganise what these
instruments into a three-layer system of categories based upon various learner preferences (Curry, 1987). These can be arranged in layers like an onion. The outer layer is based upon instructional and environmental preferences; the middle is based upon information processing preferences and the inner layer is based upon personality-related preferences. Because this study focuses upon the processing of information, only the categories that focus upon information processing are discussed.

Table 2.2 summarises the learning style inventories based upon information processing preferences.

Table 2.2: Learning style inventories based upon information processing preferences (Curry, 1987).

<table>
<thead>
<tr>
<th>Authors</th>
<th>Inventory Title/ Number of Questions</th>
<th>Reliability &amp; Validity (Curry, 1987)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biggs</td>
<td>Study Processes Questionnaire 42 items</td>
<td>high reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fair validity</td>
</tr>
<tr>
<td>Entwise &amp; Ramsden</td>
<td>Approaches to Studying 64 items</td>
<td>good reliability &amp; validity</td>
</tr>
<tr>
<td>Hunt</td>
<td>Paragraph Completion Method 6 items</td>
<td>fair reliability &amp; validity</td>
</tr>
<tr>
<td>Kolb</td>
<td>Learning Style Inventory 12 items</td>
<td>strong reliability &amp; fair validity</td>
</tr>
<tr>
<td>Reinert</td>
<td>Edmonds Learning Style Identification Exercise N.A.</td>
<td>poor reliability &amp; no evidence of validity</td>
</tr>
<tr>
<td>Schmeck, Ribich &amp; Ramanaih</td>
<td>Inventory of Learning Process 62 items</td>
<td>The most highly rated</td>
</tr>
<tr>
<td>Schroeder</td>
<td>Paragraph Completion Test 5 items</td>
<td>good reliability &amp; fair validity</td>
</tr>
</tbody>
</table>

The inventories in table 2.2 are based upon information processing preferences and relate to an individual's cognitive approach to the assimilation of information. Of the 7 inventories mentioned the highest rating (based upon reliability and validity) was given to Schmeck, Ribich and Ramanaih and this was followed by Kolb. Kolb's learning theory was adopted for use during this study and is discussed in more detail.
David Kolb's (1971, 1984) learning style inventory arose from his theory of experiential learning. This theory draws upon the work of Dewey (1938) who emphasised the need for learning to be grounded in experience. Kolb also emphasised the importance of active learning and applied some of the ideas of Piaget (1971) who described intelligence not as innate but the result of interaction between the person and the environment.

The four step process of experiential learning proposed by Kolb involves concrete experience, reflective observations, abstract conceptualisation (creating generalisations which guide further action), and active experimentation (testing what has been learned in a new situation). His inventory of learning styles identifies a person's preferred learning style and places them into one or more of four quadrants shown in figure 2.7.

*Figure 2.7: The four quadrants of Kolb's Learning Style Inventory.*

<table>
<thead>
<tr>
<th>Concrete experience</th>
<th>Reflective observation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concreteness</strong></td>
<td><strong>Abstractness</strong></td>
</tr>
<tr>
<td>Quadrant 1</td>
<td>Quadrant 2</td>
</tr>
<tr>
<td>Accommodator</td>
<td>Diverger</td>
</tr>
<tr>
<td>Doing</td>
<td>Imaginative</td>
</tr>
<tr>
<td>involved</td>
<td>emotional</td>
</tr>
<tr>
<td>impatient</td>
<td>people</td>
</tr>
<tr>
<td>people</td>
<td></td>
</tr>
<tr>
<td>Quadrant 4</td>
<td>Quadrant 3</td>
</tr>
<tr>
<td>Converger</td>
<td>Assimilator</td>
</tr>
<tr>
<td>Unemotional</td>
<td>Conceptual</td>
</tr>
<tr>
<td>things oriented</td>
<td>less practical</td>
</tr>
<tr>
<td>people</td>
<td>people</td>
</tr>
</tbody>
</table>

It needs to be noted that terms "assimilator" and "accommodator" describe learning preferences.

The Learning Style Inventory (Kolb, Rubin & McIntyre, 1974) was designed to assess a student's method of learning. As they take the inventory, learners give a high rank to those words which best characterise the way they learn and a low rank to the words which are least characteristic of their learning style. Different characteristics described in
the inventory are equally good and the aim of the inventory is to describe how students learn, not to evaluate what they have learnt.

Learners whose dominant learning style is located in the first quadrant are described as "accommodators" who grasp experience through concrete experience and transform it through active experimentation. They are risk-takers and do well in situations where they have to adapt to new circumstances. Learners whose dominant learning style is located in the second quadrant are described as "divergers" who grasp the experience through concrete experience and transform it through reflective observation. Kolb claims that such people are imaginative, generate ideas, and are generally people-oriented and emotional. Learners whose dominant learning style is located in the third quadrant are described as "assimilators" who grasp experience through abstract conceptualisation and transform it through reflective observation. They are good at creating theoretical models, less interested in people more interested in concepts. Learners whose dominant learning style is located in the fourth quadrant are described as "convergers" who grasp experience through abstract conceptualisation and transform it through active experimentation. They quickly move to solve problems.

Kolb's learning style inventory has stimulated the development of at least 7 variations (McCarthy, 1987). McCarthy developed a version that was based upon Kolb's model and she applied Kolb's theory to a complete learning system known as 4 Mat. She contends that traditional instruction does not address all learning styles and this disadvantages some learners. The 4 Mat system of instruction is designed to help instructors to plan systematic instruction that creates a variety of learning experiences that will ensure that all learning styles are catered for during a series of lessons.

Another inventory was developed by Gregorc and Wardm (1977), modified in 1982 (Gregorc, 1982), and updated by DePorter (1992, pp 125-127). This inventory has been successfully used to ascertain learning styles by DePorter (1992) and Dryden and Voss (1994). All of the learning style inventories discussed are based upon the four dimensions originally proposed by Kolb: concrete experience, reflective observation, abstract conceptualisation and active experimentation.
Kolb's learning style inventory was employed in this study. The instrument has also been used in research with computer-based concept mapping tools (Kessler, 1995). Kessler's study examined the relationship between cognitive style (as measured by Kolb's instrument) and total concept map score (based upon the criteria of Novak and Gowin, 1984). Kessler found no significant relationship between learning styles and concept map scores, but other researchers (Schreiber & Abegg 1991; Reiff & Powell, 1992) reported significant findings in different contexts. For example, Schreiber and Abegg (1991) reported that the total concept map scores (as measured by Novak and Gowin's procedure, 1984) were related to the preferred learning styles of Quadrants 1 and 3 (accommodators, assimilators) as described by Kolb's instrument. The variant results that Kessler reported may have occurred because the interrater reliability of concept map scorers was low. A similar criticism could be made of the other studies because the reliability of the scoring procedure for concept maps has been questioned by several researchers (Jonassen, 1996; White & Gunstone, 1992; Shalveson, 1993).

A different perspective on learner preferences for certain types of information was taken by Bowen (1992). This study examined the way learners accessed relevant information chosen to assist them to solve problems. It examined the strategies adopted by learners when they could access hints to help them solve problems. The findings showed that learners adopted one of the following five strategies. Some were determined to solve the problem without resorting to hints; others requested a hint after giving the challenge a good try; another group of learners pursued a hint only far enough to get an idea and then proceeded with the challenge (that is students exited the hints early); others went freely to the hints as if they were tutorials to be completed before attempting the challenge; and finally a few students examined the hints after completing the task to see what suggestions were made. Bowen claimed that the final strategy could be valuable as it helped students to formalise and generalise the techniques they employed.

Bowen recommended that students be shown a variety of learning strategies when they learn to solve problems as they may need to employ different approaches when challenged to solve different problems. He also found that inventive students were more likely to tackle a challenge with vigour if it appealed to them. Also these students were
more likely to use trial and error, but they were students who were not the highest achievers.

Learner-centred strategies emphasise methods requiring greater learner responsibility for assessing their needs and seeking appropriate information (Wittrock, 1974). While we can provide cognitive support tools such as menus and indexes to permit access to needed information, we cannot be sure that the learner has the ability and the motivation to use them correctly. More research is needed into the relationship among preferred cognitive tools, learner cognitive requirements and cognitive styles.

Another approach was taken by Stanton and Baber (1992) who assert that cognitive styles are related to a predisposition of behaviour, whereas cognitive strategies are the translation of predisposition in combination with the multi-factorial environmental situational social variable. Ferry, Hedberg and Harper (1996) found that they could identify two cognitive strategies that learners attempted to apply to a hypertext learning environment. These were described as sequential and goal oriented. Sequential users of hypertext attempt to use the materials in the 'order' that it appears. Goal-oriented users use strategies to find specific information that they require. Similarly, Stanton and Baber (1992) identified sequential users of hypertext and found that they wanted to use a structured overview screen for navigation purposes. However, they also found that it may be necessary to provide some initial constraints otherwise this may lead to a situation of 'taught helplessness' due to an oversupply of information.

Hypertext learning environments can be designed to cater for various learning styles, but a certain amount of judgement is needed by the instructional designer. If the environment is too organised and only suits a particular learning style, then individuals who approach the material from another perspective may be frustrated when they try to assimilate the materials into their cognitive structure (Hammond & Allinson, 1991; Jonassen, 1988; Underwood, 1988; Tripp & Roby, 1990). Also if the learning environment is unstructured, then cognitive load associated with navigation will reduce its effectiveness.

Applying the research to educational settings

In a society where work is becoming computer based, 'school work' cannot forever resist the change. Television and video technology already has profound effects on
education such as the decline of print culture and the rise of visual culture, low tolerance for boredom and the loss of innocence for children (Postman, 1992). Already large amounts of information in digital form are freely available to learners who have the hardware, the software and the cognitive skills required to access and search the information and then manipulate it so that it has personal meaning.

Some learners have the skills needed to participate in this digital learning environment, but others do not and their learning is at risk. It is not good enough to simply spend more and more money on hardware and software without addressing the issue of how computers and their associated software can be used to enhance the process of learning rather than just providing access to information. Many homes already possess extensive sources of information in the form of printed text, radio, television, video, internet access and computer software, yet not all the occupants of the home take advantage of these sources of information. The same applies to educational institutions and if we reflect on the last twenty years or so of educational computing, then it is likely that we will conclude that there is little in educational computing that is vital to education as it is practised in schools. There is a need to integrate hardware and quality software into schools so that computer-literate teachers and students can become skilful, reflective and mindful users of information. McKenzie (1996) further expresses this point in the following statement:

"Unless students have a tool kit of thinking and problem-solving skills which match the feasts of information so readily available, they may emerge from their meal bloated with techno-garbage, information junk food... We must guide our students to become infotectives. What is an infotective? (It is a) student thinker capable of asking questions about data (with analysis) in order to convert the data into information (data organised so as to reveal patterns and relationships) and eventually into insight (information which may suggest action or strategy of some kind) " (McKenzie, Jan./Feb.1996)

The behavioural and cognitive views of learning discussed earlier in this chapter tend to support two conflicting views of education: the didactic information-transmissive view, and the constructivist view which suggests that teachers should be facilitators who help children construct their own understanding and develop their own ability to carry out challenging tasks. These different views of education are likely to influence the way information technology is used in classrooms.
Postman (1992) suggests that there are already three different uses of technology in classrooms: tools such as word processing, graphing, communication electronic mail; integrated learning systems that tutor and keep records of student progress; and simulations and games. He argued that the tools will be developed first because they allow a great deal of user and instructor flexibility, and later the others will follow. Salomon, Perkins and Globerson (1991) supported this position and asserted that such tools mindfully engage learners in the tasks affordable by these tools. Jonassen (1996) expressed the same concept when he said "when students work with computer technology, instead of being controlled by it, they enhance the capabilities of the computer, and the computer enhances their thinking and learning" (p.4).

**The design and presentation of cognitive tools that facilitate learner processing of information**

The following suggestions come from the models of learner information processing discussed previously.

- New information should be compatible with the way the learner represents knowledge held in long-term memory. Therefore we need to understand how the learner employs his/her schema to represent his/her current knowledge. Strategies such as concept map construction may help to reveal some of the structure of the learner's schema (Holley & Dansereau, 1984; Novak & Gowin, 1984; White & Gunstone, 1992).

- We should require the learner to process the material in depth. Strategies such as embedded questions and problem-solving may be needed to ensure that this occurs (Craik & Lockhart, 1972; Holley & Dansereau, 1984).

- We should provide opportunities for the learner to produce greater degrees of elaboration via reorganisation or dual encoding. Concept maps may be a suitable strategy for learners to employ (White & Gunstone, 1992).

- We should provide a reconstructive retrieval mechanism. This could take forms such as a graphic organiser, a structured overview, or learning log. A learning log (Cambourne, 1988) is a personal diary kept by the learner. The entries are a record of the learner's reactions to current learning experiences.
Advocates (Cambourne, 1988) claim that regular use of such a device assists the learner to understand their own learning processes. When shared with others, the learning log provides an insight into another person's learning processes as told in their own voice. Such a device can help learners employ metacognitive strategies to control their own mental processes.

- We should provide for bottom-up extraction of top-level schemata. Again strategies such as a graphic organiser, a structured overview, or learning log may be employed.

- Transfer mechanisms should be included. Strategies that encourage automation support low-road transfer include the familiar drill and practice procedures. Another strategy is the use of electronic performance support systems that provide immediate assistance at the time. Advocates of this form of support (Gery, 1989) claim that this form of support will be more effective than "traditional" computer-based drill and practice training.

- During high-road transfer, knowledge and skills are abstracted from their present context and deliberately reapplied in a new context. The processes involved in the construction of a concept map may support high-road transfer because the learner has to abstract information from its present context and re-construct this information into a schematic network that reflects their present understanding.

- There needs to be greater emphasis on the learner's role in mediating interactions. Learners are not viewed simply as responders to externally generated questions or queries, but as controlling the degree to which information is selected, organised and integrated (Mayer, Dyck & Cook, 1984).

- Cognitive engagement is influenced by the nature of the presentation stimuli, the associated response requirements and the consequences of the responses (Hannafin & Reiber, 1989).

- Responses made with minimal effort offer objective evidence of interaction, but little about the degree to which the relevant concepts have been mastered.
Meaningful learning is more completely integrated with existing schema, presumably increasing both the utility of the knowledge and the potential for transfer to untaught problems.

The technology that supports people with such environments (enriched learning and information environments) can be seen as a performance system of conceptual and technical tools that enhances information management, and productivity through embedded guidance and a problem-solving environment (Derry & LaJoie, 1993).

**Evaluation of cognitive tools that facilitate learner processing of information**

David Jonassen (1996) suggested that there are six basic pedagogical criteria that should be applied to the evaluation of cognitive tools such as mindtools.

- They can be used to represent knowledge (how someone represents content or personal knowledge).
- They are generalisable (can be used to represent knowledge in different content areas).
- They engage the learner in critical thinking about the subject.
- The skills acquired are generalisable and transferable to other contexts.
- The formalism embedded in the tool is simple but powerful as it encourages deeper thinking and processing of information.
- The software should be easy to learn and the mental effort needed to learn the software should not exceed the benefits.

The concept mapping tools in this study were designed to meet these criteria as they belonged to the mindtool category as defined by Jonassen (1996).

**Part 2: Summary**

Computer-based learning environments show promise in assisting learners to process new information. In particular, hypertext-based learning environments that make use of cognitive tools can assist learners to form associative links with existing semantic
networks already held in long-term memory. Such tools should assist learners to process new material in depth and to re-organise it so that it can be more easily absorbed into long-term memory.

Abstract representational schemes such as concept mapping may be gainfully employed as cognitive tools but they may be context-specific and appeal more to one learning style than another. Ideally, they should be independent of context and learning style and be easy to use so that the cognitive load associated with their use is kept to a minimum otherwise their use will be self-defeating. During this study, concept mapping was employed as an abstract representational scheme because the subject matter was science-based and much of the past research associated with concept maps related to science education.
Chapter 3 Learner Interpretation of Graphs and Tables

The previous chapter provided a theoretical perspective to the study by discussing relevant models of learning and pertinent theoretical research. It is now appropriate to discuss physiological and cognitive mechanisms that may help researchers to understand how learners process information presented in graphs and tables. In addition, structural features of graphs and tables that support learner processing of information are discussed.

This chapter will also examine previous studies about learner interpretation of graphs and tables. Not only are these a source of appropriate research techniques, but they also guide in the development of suitable cognitive tools.

The chapter is divided into two parts. Part 1 examines the findings from research that are relevant to the interpretation of graphs and tables. There is no specific discussion of learner interpretation of text in this section as the general principles that were applied in this study were discussed in Chapter 2. Instead, relevant discussion of text will be integrated into the context of learner interpretation of graphs and tables.

Part 2 of this chapter presents a summary that synthesises the main ideas that apply to the design of the cognitive tools from Chapters 2 and 3. It presents the initial design criteria and finally the section ends with a brief discussion of the research questions that arose from this review of the literature.

Part 1: Relevant research relating to the interpretation of graphs and tables

Modern technology can provide learners with information that comes in a variety of formats that can be seamlessly integrated to form unique learning experiences. In the past we could attempt to classify information and to understand its effect in terms of a conceptual model and Dale's cone of experience (1969) is an example of how this was attempted. Dale's model (1969) placed "direct purposeful experience" at the base and "verbal experience" at the apex. The model was based upon the assumption that greater
sensory participation by the learner resulted in more efficient and meaningful learning. Thus information presented in the forms just below the apex was considered to provide less sensory experience and stimulation than those experiences located at the base of the cone (see Figure 3.1).

Figure 3.1: Dale's Cone of Experience (1969)

However, Dale's model is only one way to represent the presentation of information and was devised well before the information technology revolution. It did not take into account the fact that modern interactive multimedia presentations can present the learner with many forms of information that can be combined with each other. While the model may not be appropriate for use in an information technology era, it can still serve as a referent for instructors when they integrate multimedia packages into holistic learning experiences.

A different approach was taken by Winn (1987) who claimed that researchers would be better served if they arranged the various forms of information along a continuum with realistic pictures at one end and written and spoken language at the other (Dale, 1946; Knowlton, 1966; Levie & Dickie, 1973; Flemming & Levie, 1978). The rationale for this classification is based upon the notion that realistic pictures resemble what they stand for while the words chosen to describe them are more arbitrary and conventional (Knowlton, 1966); or that pictures describe phenomena, while words name and explain
them (Doblin, 1980). Winn claims that these forms of information may be arranged in boxes along a continuum that extends from pictures to words (Winn, 1987). Again this classification scheme was more useful when information appeared in static form in books and posters, but dynamic, electronic, digital storage of information allows users to reconstitute information into a variety of forms that can combine many of these features.

Figure 3.2 represents a slightly different way of looking at this issue because a linear representation that places these various modes of information into boxes may give an inappropriate representation of what happens in real as opposed to theoretical situations. Usually learners have access to a combination of various forms of information and, as they interact with them, they construct meaning. Different forms of information place different cognitive demands on the learner and, in a situation where the forms of information presented are constantly changing, the cognitive demands are also constantly changing. Cognitive load can occur when a learner moves from one form of information to another because their attention can be split among these different forms of knowledge.

*Figure 3.2: A schematic diagram of the cognitive demands associated with various forms of information presentation.*
The figure attempts to represent situations where the learner moves from one form of information to another in a unique pattern of interaction that helps him/her to generate meaning. That is, the learner does not act as a passive receiver of knowledge but actively explores and manipulates it to construct their own meaning. Therefore, the learner's cognition is adaptive and serves to organise his/her experiential world.

This interpretation is based upon a constructivist philosophy which espouses the notion that as humans interact with the world they construct their own experience and knowledge. Each learner comes to any learning situation with previous life experiences that influence how they construct meaning from the information presented. However, it is likely that learners need to use strategies that assist them in the construction of knowledge from these various forms of information presentation. Moore (1993) suggests that a mechanism is needed to help learners process graphs, diagrams and texts, and he proposes that training in metacognitive strategies may have a positive impact. Concept mapping is a metacognitive strategy that may provide learners with a means of constructing meaning from these various forms of information presentation. During this study the use of concept mapping as a metacognitive support strategy to enhance learner processing of information contained in text, graphs and tables was investigated.

The use of graphs and tables to support learning

William Playfair (1801) was one of the first people to use graphs to illustrate data and his publication of a "The Statistical Breviary:..." showed how the resources of Europe could be displayed visually (see Plate 1 in Appendix 1). He argued that "...it occurred to me that tables are by no means a good form of conveying such information..." (p.3) and that we can use the graphical "mode of representation to facilitate the attainment of information and aid the memory in retaining it: which two points form the principal businesses of what we call learning or the acquisition of knowledge." (Playfair, 1801, p.14). While the idea of using graphs as a visual display of information is nearly 200 years old, and our dependence on graphs to present data has grown exponentially (Weintraub, 1967), we still do not fully understand the cognitive processes people employ when they interpret them.
There are a variety of arguments put forward to explain why graphs and tables should be used to support learning. MacDonald-Ross (1979) suggest that visual representations such as graphs, maps, and charts use an entirely different type of logic based on the meaningful use of space and the juxtaposition of elements in a graphic, and this enhances learning. Other researchers (Winn, 1987) suggest that it just may be that graphs and tables can offer more information in the available space than words. However, (Olson, 1977) believes that the explanation is more complex and that visual displays of information (such as graphs) are effective because they make use of under-utilised visual abilities. He contends that schooling encourages learners to rely upon a narrow set of cognitive skills because it is biased toward verbal discourse and verbal representation of information. When we present information in graphical form, we encourage learners to use cognitive skills that are different to those they normally employ. As they master new cognitive skills learners may become more productive because they transfer these skills to other tasks.

Other researchers have proposed that graphs and tables support learning because of physiological reasons and these are briefly discussed below.

**Physiological mechanisms that may explain why graphs and tables support are effective in conveying information to learners**

The human eye is also very good at recognising geometric shapes and Pinker (1981, 1983) attributes the success of graphical forms largely to this ability. While the human eye is very good at recognising global or general features, it cannot easily encode specific details (local features) without the support of other strategies such as counting or measuring. Some researchers associate the advantages of graphical displays of information with physiological mechanisms and Sless (1981) reminds us that the human eye is well suited to pattern recognition, but very poor at quantitative judgments (Sless, 1981, p.147). Therefore it may be useful to provide humans with cognitive support that makes it easier for them to make quantitative judgments associated with graphs and tables.
Research into learning with the right cerebral hemisphere suggests that this side of the human brain is used in the interpretation of spatial patterns such as those presented in graphs and diagrams. In the 1960's Roger Sperry and his students began their historic split-brain experiments and were able to test separately the thinking abilities of the two surgically separated halves of the human brain (Sperry, 1964). They found that each half of the brain had its own separate train of conscious thought and its own memories. The left brain handles language and logical thinking, while the right brain "does things that are difficult to put into words" (Blaksee, 1980, p.6). For example, by thinking in images instead of words the right brain can recognise a face in a crowd or put together pieces of a jig-saw puzzle. Further research in educational settings produced evidence that supported the notion that not only do the two hemispheres of the brain process information differently, but the right hemisphere is better suited for processing spatial information (Hellige, 1980; Wittrock, 1980). Table 3.2 after Rose (1985) summarises the probable functions of the two hemispheres of the brain.

Table 3.1: Probable functions of the hemispheres of the brain (Rose, 1985)

<table>
<thead>
<tr>
<th>Left brain</th>
<th>Right brain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>emphasises</strong>: language, mathematical formulae, logic, numbers, sequence, linearity, analysis, words of a song</td>
<td><strong>emphasises</strong>: forms and patterns, spatial manipulation, rhythm and musical appreciation, images and pictures, daydreaming, dimension, tune of a song</td>
</tr>
</tbody>
</table>

It can be seen that the right side of the brain is more likely to be involved in the processing of spatial information presented in graphs, but the left side of the brain is probably more involved in the interpretation of tables.

Some researchers such as Toth (1980) suggest that graphs and diagrams are successful in conveying information because they call upon the right-brain processes that would otherwise not be used (Toth, 1980). Several other researchers claim that traditional schooling is predominantly "left brained" and that the "right brain" has been neglected (Blakeslee, 1980; Sylwester, 1981). Out of research associated with learner use of the right side of the brain to process information, grew a movement that supported the use of educational strategies that encouraged right-brained processing of information (Grinder, 1989; Rose, 1985). Such strategies emphasised visualisation and employed techniques such as mind mapping (Buzan, 1995) which purported to link right brain processing of visual information and left brain processing of verbal information (Margulies, 1991).
Margulies (1991) asserts that this "holistic" approach stimulates both cerebral hemispheres and aids information processing and memory. It may be that mapping techniques that use visual tools (such as concept mapping) have similar effects.

Some researchers claim that learning can be accelerated through "holistic" techniques that stimulate right brain as well as left brain processing of information (Rose, 1985). This supposition is based upon the notion that much of the information learners receive is processed by the left brain, and techniques that encourage greater use of the right brain can greatly increase learner capacity to process and remember information. While these claims have not been substantiated across large groups of learners, they have generated a large amount of interest in learning activities that stimulate right brain processing of information (Grinder, 1989).

Besides mapping, other strategies to encourage right brained processing of information have included: the association of concepts or words with images (eg. the Lozanov method of foreign language instruction combines images with relaxation exercises to achieve what is claimed to be "accelerated learning", Lozanov, 1978); the placement of concepts into a logical arrangement of images such as rooms in a building (Blakeslee, 1980); and the use of teacher behaviour (Fenker & Mullins, 1982) to encourage visualisation (eg. still arms and body, flat high voice, talking at a slow pace and increasing the length of sentences). The claims that have been made about the benefits of such strategies relate specific contexts and further research is needed before claims can be made in more general contexts.

**Cognitive mechanisms that may explain why graphs and tables are effective in conveying information to learners**

Many studies associated with cognitive mechanisms describe dichotomies whose poles are pairs of abilities, one of which is maintained to be associated with graphic representation. For example Paivio (1971, 1972, 1983) proposed that a "dual encoding" theory could be used to explain how humans are capable of encoding information both imaginally and verbally. This theory is important as it recognises that learners are capable of "dual encoding" of both visual and verbal information when they interpret verbal and
visual information found in graphs. Also, this notion builds upon the split brain research of Sperry (1964).

Other research has been conducted into mental abilities relating to spatial and verbal processes (Snow, 1980), but the results are context specific. For example, it has been proposed that certain types of information are stored in memory as image-like structures which retain some, though not all of the properties of the image (Anderson, 1978; Kosslyn, 1980, 1981). Pylyshyn (1973, 1981) disputed this view and claimed that the information may be stored as propositions in language-like structures. A conclusion that can be drawn from a series of studies designed to clarify this dispute is that "graphic forms encourage students to create mental images that, in turn make it easier for them to learn certain types of material" (Winn, 1987, p.159). These findings describe outcomes of learner processing of information in graphical form, but they fail to describe how learners read graphs and process the information they contain. Research related to these issues has also been reported by Janvier (1978) and Preece (1985), and will be discussed later in this chapter.

Another approach was to consider the simultaneous and successive processing of information by learners. The bulk of this work focused on labelled diagrams rather than graphs and tables; however the findings may be transferable. Winn (1987) claimed that the ability of learners to simultaneously scan all the information (text and graphics) they need to understand labelled diagrams assists them to quickly derive meaning. Information processing is also enhanced if learners trace logical paths through diagrams, so that they can understand relationships among parts in a process. Thus the more capable learners are likely to successively process sequences of information in labelled diagrams, and simultaneously scan pictures and related labels.

In the area of reading there has been a great deal of research associated with the use of graphic organisers with text and many strategies are available (Morris & Stewart-Dore, 1984), but there is also evidence that graphic organisers can improve the performance of learners presented with text or labelled diagrams (Jonassen & Hawk, 1984). The strength of the graphic organiser appeared to be that learners could create an overview of the whole material. Hyerle (1996) contends that organisers are like maps and act as
guides and visual tools allowing us to make these maps which represent connections among ideas and concepts.

**Research related to the instructional effectiveness of graphs and tables**

Much of the research conducted into the instructional effectiveness of graphs and tables has been criticised by Winn (1987). In his review of the research related to this topic he makes five important points.

1. Many studies fail to clearly define the instructional function of the graphic used. The experimental effects cannot be linked to specific features of the graphs or tables. Therefore, the best conclusion that can come from this form of research is that the graphs and tables may have had an effect, but we cannot identify any factors that may explain why this happened.

2. A great deal of research has been concerned with whether the graph or table has an effect on what students learn. Many are comparison studies that compare a graphical treatment with a textual one. Again the emphasis is on describing effects rather than explaining them.

3. Winn (1987) states that the research associated with the fields of semantic networks, concept mapping and spatial learning theory (Holley & Dansereau, 1984) may prove to be very fruitful as they deal with the psychological factors that are fundamental to visual processing.

4. Very little research has been conducted on the instructional effectiveness of graphs and tables.

5. The effectiveness of graphics cannot be explained in a simple way, because in a substantial number of studies the experimental effects were found to depend on learner ability and on the nature of the learning task.

**Structural features of graphs and tables that convey information to learners**

Graphs and tables convey meaning by exploiting the patterns formed by the data elements they contain and by the sequences that these elements form. These structural features of
sequence and pattern can make it easy or difficult for learners to process the information presented in graphs or tables (Winn, 1987). Tables convey sequence through the order in which elements are encountered; usually we read them from top to bottom or left to right. They emphasise class memberships, by means of column and row headings. By way of contrast graphs exploit the convention that higher on the page or the y-axis, means larger or more value, and the general shape of the line or pattern of bars conveys a general sense of the relationships conveyed.

Research with tables has shown that simply arranging the data elements into groups improves learner ability to understand and remember them (Decker & Wheatley, 1982). Furthermore, if the elements are grouped according to some conceptual structure (for example taxonomy), then their arrangement can reinforce that structure (Rabinowitz & Mandler, 1983). In his review of the research relating to tables Winn (1987, p.177) concludes that "even the simplest spatial organisation of elements into meaningful clusters has the potential to improve learning." This research is also supported by the studies of Chandler and Sweller (1991, 1994).

More recent research associated with cognitive load, (Chandler & Sweller, 1991; Sweller, 1994; Sweller & Chandler, 1994) built on this research and suggested that "effective instructional material facilitates learning by directing cognitive resources toward activities that are relevant to learning rather than toward preliminaries to learning" (p.293). This describes a situation where well designed cognitive tools could be used to reduce cognitive load associated with learner processing of information in graphs and tables.

**Research related to the interpretation of graphs**

"Interpreting a graph consists of putting into verbal form information, regarding a situation, given a graphical form" (Janvier, 1978).

Two dissertations form the focus of this part of the chapter. The first was a PhD dissertation completed by Claude Janvier in 1978, and the second was a PhD dissertation completed by Jenny Preece in 1985. Both studies were chosen because the methods employed interview techniques that produced findings that described the cognitive strategies learners used to understand graphs. During this study subjects were
interviewed to find out if they employed similar cognitive strategies to those identified by Janvier and Preece.

**Janvier's study**

This study examined how learners interpreted complex cartesian graphs. Survey methods were not employed as Janvier found that many of the seventy studies related to this topic were based upon survey methods that yielded contradictory results. He claimed that this occurred because of a lack of clear definition of the variables, and "the blind manipulation of testing and statistics" (Janvier, 1978, p.2.8). Instead he employed interview techniques.

During his study 20 students aged 11 to 12 years of age, plus a few aged 14 and 15 were interviewed. His interview techniques evolved during the course of the study, with the first session interviews being less standardised than the others. The pattern of questions was loosely followed, but became more standardised in later interviews as he became more confident in his ability to probe the reasoning employed by learners. He believes that "one must pay sufficient attention to the learning naturally taking place during the interview" (p.4.5) as this may give further insights into how the learning is taking place.

The questions he chose were divided into two categories: those that were regarded as easy and involved ideas not expected to correlate with other ideas; and those that require more processing of information and are expected to correlate with other ideas.

**The findings**

The interview data confirmed that the problems presented were basically new to the subjects, and on the whole "regurgitation of memorised answers or blind application of well-known rules were rare" (p.4.7). His findings produced organised description and classification of the difficulties met by the pupils and of the strategies used. These difficulties were compared across tasks and across years.

Janvier claimed that his study showed that interpretation can be either guided by the semantic content of the question or by the symbolic outlook of the graph. Two processes are in operation: one obtains information provided in the question (the situation or context) and relates it to the graph, and the other scans graphical features in order to derive meaning. He claims that graphical interpretation is "a subtle mixture of these two
processes" (p.9-42) and that "graphical interpretation can be best described as a progressive integration of the various pieces of information conveyed by the graph with the underlying situational background" (p.3.6).

Furthermore, there is no interpretation without situation (context) as any learner has personal knowledge already present in his/her mind before (s)he tackles any question. The graph and question convey definite information which constitutes a definition of the situation and this is analysed through a process involving a continuous reference to the underlying background knowledge of the learner. Figure 3.3 displays Janvier's model of this process. The vertical arrow labelled "as the direction of graph - situation prevails" shows that the process is seen as starting at the top of the model and finishing at the bottom.

*Figure 3.3: A model of the processes involved in interpreting graphs (after Janvier, 1978).*

When the learner is first given a graph to interpret, (s)he starts with either the situation (context) or the graph, but as attention is focused on the graph, its features become meaningful and provide the learner with greater understanding of the original situation.
Gradually the original situation is referred to less and less and becomes integrated with the graph which becomes the principal conveyer of meaning. While this model is plausible, there were no clear examples of gradual integration developing.

When Janvier examined the coordination of these two processes involved in graphical interpretation he found that the coordination between the two modes of information presented required learners to simplify and memorise one or both. Pure visual simplification appeared to be insufficient and "verbal" summaries spelled out during the checking of an hypothesis appeared to literally replace the graph, but it was also necessary for various global features such as rises and falls, and local features such as specific labels on axes to be handled in order for interpretation to be successful.

The following features of graphs were identified by Janvier as global: maximum and minimum; intervals over which the function increases; intervals over which a variable is less than, greater than, or equal to a given constant (plateau); drops and rises of curves between plateaux or extreme points; the general shape (up or down) or curves; discontinuity; patterns that give rise to cycles; steady rates of change; symmetry; extrapolation; interpolation (asymptotes); dispersion of a graph and difference in shape measured by area; and many curves on the one graph.

He claimed that "generally the interviews have shown the key to success in the translation skills lies in the possibility to derive an equivalent of one mode - as a mental rich image - on which is based the execution of the other representation" (p.10.8). The interview data were consistent with Paivio's views (1972) that the mental representation of a dynamic situation is not sheer reproduction like a film, but an internal reconstitution done by the mind. During the process of interpretation mental reconstruction varies in its association between the situation and the graph, but gradually becomes more articulated with the graph itself.

Nine specific skills were considered to be important for the interpretation of graphs. These are discussed below:

1. Reading skills - Janvier found that competence in reading scales and handling units were the main areas that needed further support. He suggested that learners may be supported with indirect exercises that extended over a long period of time.
2. **Interpolation** - Janvier suggests that learners should have access to a table of values associated with the graph as this makes interpolation more accurate.

3. **Comparison of two variables** - the use of language to describe comparisons assists some learners to compare values but the evidence was not always conclusive.

4. **Interval of increase** - the use of language to describe increases assisted some learners to accurately describe and measure intervals of increase but the evidence was not always conclusive.

5. **Rates of change** - less able students have difficulty answering questions that relate to rates of change and need support. This may relate to cognitive load as they have to read the graph and interpret scales on two axes.

6. "**Graphical awareness**" - pupils who were more aware of the meaning of the symbols presented by the graph were more likely to choose the correct answer to questions.

7. **Association of the gradient with the situational feature** - in simple situations (e.g., temperature versus time graphs) students who were aware of the relationship between the gradient and the situation were more likely to choose the correct answer. However, with complex graphs the results were less conclusive.

8. **Association of graphical features with experimental details** - students with "above average ability" who had access to the table of values associated with the graph were more likely to be successful in answering the question.

9. **Co-ordination of the graph with pictures** - some students could correctly relate the events depicted in graphs to sequences of pictures. In most cases they were more likely to successfully interpret these graphs.

Janvier claimed that six classes made up an "index of competence in graphical interpretation". These were: comparing values; recognising changes in values; linking of graphical features to a situation; linking a graph to a picture; numerical awareness of graphical patterns; and capacity for abstraction (general mathematic ability). While this
may be a useful descriptive classification, it does not offer any explanation of the cognitive processes involved.

**Further studies recommended by Janvier.**

During a discussion of points for further studies Janvier raised the notion that graphs can be used to "teach" science concepts (p.15.4). Furthermore, children's concepts could be investigated through the use of graphs as a tool to probe their mental structures. A related idea is to develop higher order learner skills such as knowledge construction and to apply these skills to represent the knowledge that learners gain when interpreting graphs and tables.

Another issue raised was the transference of skills. If we consciously provide practice in them, they may transfer to new contexts but Janvier is not certain whether verbal mediation is needed. However, if verbal mediation is required, the form it takes could be either direct teacher instruction or computer supported instruction.

Finally, Janvier calls for further investigation of the "graphical reasoning" expected from science pupils at the end of secondary schooling. He believed that such an investigation would yield important data that could influence teaching practices, particularly in science and mathematics.

**Synopsis**

Any graphical interpretation involves analytic and synthetic components. If learners choose to make use of global or local features (specific labels) in isolation, they will be ineffective as they have to link the information to a situation. The development of skills in handling global and local features of graphs reduces learner cognitive load associated with this aspect of the process and makes interpretation easier and more efficient. Also the development of vocabulary skills associated with the context is a strategy that actively engages the learner to reflect on, and verbally re-construct the information presented.

Finally, the use of tables that contain the data presented in graphs helps learners to analyse graphs. Later studies by Janvier (Janvier, 1980) reported that learners use different types of reading styles when interpreting graphs and the kind of reading style used contributes significantly to the success (or lack of success) of graph interpretation.
He claims that learners read graphs in an absolute or a relative manner. Absolute reading can occur with little or no interpretation and focuses on specific values. Relative reading is concerned with relationships between global features and trends in sections of graphs. Specific points are usually read but often little attention is paid to the exact information on the scales of the axes. Janvier claims that relative reading is better for interpreting trends because absolute reading produces too much confusing detail and this leads to cognitive overload. However, Preece (1985) argues that terms such as absolute and relative reading may not be useful concepts as some interpretation is always occurring.

Nevertheless, the notion of reading styles helped to identify the issue of cognitive overload which is suffered by many learners when they read complex graphs and tables. Later in the 1990's research associated with cognitive load (discussed earlier in the literature review) further developed our understanding of how cognitive load occurs in such situations - in particular, the effect that split attention has upon mental integration of different forms of information.

Chandler and Sweller (1991) claimed that mental integration is likely to be cognitively taxing. It is important, therefore, to save learners from unnecessary mental integration as they process new information. Where mental integration is necessary, conventional instruction may be better replaced by integrated instruction which could be performed by a suite of cognitive tools.

Janvier (1980) and Swan (1980) suggested that graph sketching exercises will help learners to improve their interpretation skills, but the development of applications for computers that directly plot graphs from data gathered by sensors may result in less emphasis on this skill. Also they provided no research evidence to support their assertion.

**Preece's study**

Preece reviewed the findings from previous studies relating to the interpretation of graphs and concluded that they pointed out trends but told us "little about why the children answered questions incorrectly" (p.2-15). She argued that interview methods are needed to understand what is really happening when children interpret graphs, because the process is complex and requires understanding of the child's thinking processes.
Preece explained when a child interprets a graph, (s)he "has to integrate the new information from the graph with her already existing knowledge of the context" (p.2-16).

Preece reviewed attempts that have been made to link events to graphs via computer animations, but found that most of the evidence was inconclusive. She claims that the reasons for this may be associated with the rigorous quantitative design of many of the studies which may have obscured some of the more interesting results.

Since her work was completed, many simple micro computer interface kits have been developed which plot graphs from data collected by sensors attached to experimental apparatus. A review of this topic is beyond this study. However, it should be mentioned that while the enthusiasm for these devices lies with the fact that they "instantly" plot graphs and generate tables (and some provide simple tools for data analysis), they still have to be interpreted. There is a danger that learners who become isolated from the context of the data may have difficulty in interpreting the graphs and tables generated.

Preece wanted "to find out what kinds of errors are made, and what strategies and conceptions are used when 14 and 15 year olds interpreted trends in single and multiple-curve graphs" (p.3-2). She also wanted to "confirm that context does have an effect and to describe the effect it has on the process of interpretation" (p3-2). Her sample consisted of nine students who were interviewed a number of times in the manner described by Janvier (1978). Another group of 144 subjects (age 14 to 15 and of mixed ability) were surveyed to collect performance information across a range of tasks related to graphs.

Over 50% of Preece’s subjects could answer straight-forward interval questions. However, learners had difficulty when they had to compare intervals. When students had to relate a graph to its context the number of correct descriptions dropped to 16%. The transcripts of the answers indicated that the context of the graph influenced the way it was interpreted.

Maxima and minima questions were correctly answered by 73% of the subjects. These findings support Janvier’s (1978) work which showed that these questions are low in cognitive demand. Some questions which displayed the graph in a less conventional manner were poorly answered. This raises questions about the effect of the form of the display on the learner processing of information.
Only 11% of subjects could describe a graph as a representation of the relationship between two variables; they found questions about the interpretation of gradients difficult and they had difficulty relating a graph to its context.

The results from more detailed investigations that followed on from her survey work showed that the context of the graph has a strong influence on the way pupils interpret the graph. Furthermore, the pupil's contextual knowledge either helps or hinders interpretation; the effect is never neutral. As Preece states: "when interpreting a graph, the pupil always brings general contextual knowledge to the task and then has to select the information which is relevant. Gradually, during the process of interpretation, the pupils will add more information as she integrates the graph and the context more fully" (p.9-3). These findings are supported by the work of other researchers (Donaldson, 1978; Johnson-Laird, 1981; Hughes, 1975).

In discussing the influence of context over the interpretation of the graph Preece mentions the work of Driver and Erickson (1983) and Gilbert and Watts (1983) which related to the alternate concepts that children develop from their everyday life experiences. Preece recognised that the subjects of her study came to the task with strongly held concepts structured from their own life experiences and these have influenced the way that they interpreted the graphs. She claimed that the context of the graph affects how the pupil interprets the graph by influencing the selection and use of concepts in the interpretation. Also the structure of the graph can stimulate thinking about a particular part of the graph or about other aspects of the context. If the context is ambiguous then the structure of the graph will have a strong influence on its interpretation.

In 1992, Preece and Janvier collaborated to examine the role of context on the ability of twenty-three 14 and 15 year olds to interpret graphs about ecological contexts. The findings from their interviews indicated that the students were using their own contextual knowledge when they interpreted the graphs, and this impacted upon how they interpreted graphs (Preece & Janvier, 1992).

While Preece (1985) implied a constructivist approach and mentioned that prior learning influences the way learners interpret graphs, she did not formally link the term constructivism to the process of interpreting graphs. In 1994 Roth and Bowen linked a
constructivist perspective to the construction of meaning from graphs and tables, and
their study is one of the few recent studies to formally link constructivist perspective to
the interpretation of graphs and tables.

Synopsis

Preece has shown that many learners have difficulties with interpreting graphs. While
most graph work taught in mathematics is quantitative and involves activities such as
plotting and reading values, in the world outside the classroom the most usual way to use
graphs is to read global features and interpret trends in data. When teachers assist
children to interpret graphs, they need to be sensitive to the kinds of conceptions children
bring to the task and need to take into account these conceptual frameworks. Also the
way that graphical interpretation is taught in mathematics may not be appropriate for other
contexts, where different skills and concepts need to be developed.

Preece recommends that interactive computer programs be explored as a means of directly
relating the graph to its context. Sketching and interpreting programs that relate to
simulation programs are also recommended. Finally she recommends the development of
conceptual models and teaching materials that build upon her research (p.9-9), and this
study aims to extend upon this aspect of her work.

Part 1: Summary

Learners often have difficulty interpreting graphs and tables even though they are a
convenient way of displaying large amounts of information. When researchers have
attempted to understand how learners process information displayed they have usually
take one of three approaches. The first approach is based upon attempts to understand
physiological mechanisms such as learner eye movements when they read graphs, and
the function of the cerebral hemispheres of the brain (in particular the right hemisphere).
The second has been the most popular approach and focuses on cognitive components
such as information processing and mental imaging. The third approach focuses upon
the structural features of graphs and tables and how these affect the processing of
information.

The approach that focuses on structural features has also been linked to research relating
to the instructional effectiveness of graphs and tables. However, the small amount of
research conducted into the instructional effectiveness of graphs and tables has only found that their effectiveness cannot be explained in any simple way, and much more research is needed in this area.

During the last 20 years research into the interpretation of graphs and tables has received more recognition, and this may be related to the greater use of qualitative research methods, in particular interviews. Studies have shown that the interpretation of graphs and tables is an analytical and synthetic process. Learners need to process global and local features from the graph and table and then link this to information about the context. However, learners already have formed concepts that relate to the context and these have an influence on how the graph or table is interpreted.

**Part 2: Applying the findings from Chapters 2 and 3**

Part 1 of Chapter 2 focused on learning theory and in particular upon constructivist principles of learning. Part 2 of Chapter 2 focused upon how learners assimilate and accommodate new information into their existing schema. Various general strategies that involved the use of cognitive tools were discussed and these included: the use of advance organisers; concept mapping; support tools that reduced cognitive load; and support tools that facilitated transfer. A model of learning that supported a holistic approach to the introduction of learners to cognitive tools that were to be used in this study was also presented.

Part 1 of Chapter 3 focused upon studies that helped us to understand how learners interpreted graphs and tables.

The system of cognitive tools developed during this study was guided by a constructivist theory of learning (von Glaserfeld, 1989), described in Chapter 2. Relevant research findings that related to other theories of learning were also applied to the development of the cognitive tools. In particular findings associated with advance organisers (Ausubel, 1968; Novak, 1977b; Clarke, 1991), semantic networks, concept maps and information processing models of learning were applied in an eclectic manner (Quillian, 1968; Shalveson, 1974; Tulving & Donaldson, 1984; West & Pines, 1985; Heimlich & Pittelman, 1986; Jonassen, 1988; Wandersee, 1990; Novak, 1990; Jonassen, 1992a; White & Gunstone, 1992). Thus the final product was developed after taking cognisance
of previous research into learning. In the section that follows the features of the cognitive tools developed are described and linked to relevant learning theory reviewed in Part 1 of Chapter 2.

*Figure 3.4: The original plans for the cognitive tools*

Figure 3.4 displays the original conceptual diagram for the cognitive tools used in this study. These main features are described under the headings of *layout and buttons*, *special features* and *learner tracking*. Layout refers to the design of the individual screens displayed and buttons refers to the location and function of the individual on-screen buttons

**Layout and buttons**

The original prototype had a layout as shown Figure 3.4. Eight on-screen buttons are located along the right hand border of the screen. This is consistent with the findings of
Miller (1956) whose research suggested that seven plus or minus two items of information can be stored in short-term memory at any one time. The order of the buttons from top to bottom was in a temporal sequence suggested by a group of three researchers experienced in the field of instructional design (Hedberg, Harper, Cheung, personal communication, November 24th, 1994). To ensure that the labels were consistent with the functions of the buttons the same three researchers were referred to as well as ten volunteers who trialed the buttons.

The concept mapping tool was linked to the button labelled concept map. This tool contained a pop-up palette of six buttons which appeared once the concept map button was activated. The six buttons employed by the concept mapping tool mirrored the process recommended by White and Gunstone (1992) and the arrangement of the buttons in the palette was made to follow the instructional sequence which they also recommended.

A full description of the screens is left to Chapters 6 and 7 where screen-captures are displayed.

**Specific cognitive tools**

The following cognitive tools were designed to assist learner comprehension of the information presented in the tables and graphs: balloon help; a map; a sorting tool; embedded questions; and a concept map creation tool. All were designed to help the learner to assimilate and accommodate new information. They are fully described in the Chapters 6 and 7.

**Balloon help**

The learner could use a button to activate or de-activate the balloon help. This feature allows the learner control of the help. Instead of being continually available, it can be activated at the moment of need. Gery (1991) recommends that learners access help at the moment of need, however novices may forget that they have this form of help available and fail to take advantage of it (Clarke, 1992). Therefore, in this study it was sensible to begin with the help activated and then allow the learner the option of switching it off.
The sorting tool

The sorting tool in the table permitted learners to re-arrange individual data columns in numerical or alphabetical order. This made it easier for learners to compare data and to see trends in the data.

Questions

These were designed to encourage deeper processing of information.

The concept map creation tool

The concept map was designed to be a metacognitive tool that allowed learners to restructure the information into a form that was personally meaningful to them.

Table 3.2 briefly describes the cognitive tools used during this study, their purposes and some of their links them to supporting theory. The purpose of the table is not to show all theoretical links; instead it is designed to show that the cognitive tools developed had specific purposes and was supported by educational theory.

<table>
<thead>
<tr>
<th>Cognitive tool</th>
<th>Purpose</th>
<th>Supporting theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buttons</td>
<td>to link the learner to tools that assisted them to process information and to provide functional tools</td>
<td>top down, bottom up processing (Stanton &amp; Baber, 1992)</td>
</tr>
<tr>
<td>Balloon help</td>
<td>to provide &quot;just in time&quot; support</td>
<td>electronic performance support (Gery, 1989)</td>
</tr>
<tr>
<td>The sorting tool</td>
<td>to reduce cognitive load</td>
<td>cognitive load theory (Sweller &amp; Chandler, 1994)</td>
</tr>
<tr>
<td>The embedded questions</td>
<td>to encourage deeper processing of information</td>
<td>top down, bottom up processing (Stanton &amp; Baber, 1992)</td>
</tr>
</tbody>
</table>

This chapter ends with a list of the research questions that developed from this literature review. The questions are listed and briefly discussed in relation to Chapters 2 and 3.

1. What factors affect the ability of various groups of preservice teachers to interpret a set of graphs and tables?
2. What cognitive strategies do preservice teachers employ when they interpret graphs and tables?

Questions 1 and 2 relate to previous studies of researchers such as Janvier (1978) and Preece (1985). The methodology chapter outlines procedures used to verify their research and strategies employed to identify other factors that may be specifically related to the subjects of this study.

3. How do the identified cognitive strategies compare with those strategies identified by other researchers?

While the question relates to previous studies of researchers such as Janvier (1978) and Preece (1985), it also relates the work of Winn (1987) as well as that associated with cognitive load (Chandler & Sweller, 1991; Sweller & Chandler, 1994). The methodology chapter outlines procedures used to verify their research.

4. Could the instructional strategies identified by researchers (Gunstone & White, 1992; Holley & Dansereau, 1984; Cambourne, 1988) in related fields be applied to effectively introduce learners to the concept mapping tool?

This question specifically relates to the suggestions of researchers such as White and Gunstone (1992) and Holley and Dansereau (1984). It also relates to Cambourne's (1988) model of learning that supported the procedures adopted in the methodology chapter. In addition, it relates to constructivist theory as discussed by von Glaserfeld (1995).

5. What effect does the concept mapping support tool have upon the way the learners structure their knowledge?

This question relates to the research of Hyerle (1996); Jonassen (1996); Kessler (1995) and Novak and Gowin (1984). In particular the methodology chapter describes the strategies use to gather data that could be used to understand how the learners constructed their concept maps with the concept mapping tool.

6. Do the cognitive support tools assist learners to analyse information in text, tables and graphs?
This question specifically relates to the research of Janvier (1978); Preece (1985), and Chandler and Sweller (1991); and Sweller and Chandler (1994). It also relates to the research associated with "just in time" support (Gery, 1991).

7. What evidence is there that these cognitive tools had an impact upon the concepts developed by the learners?

This question relates primarily to the research of Jonassen (1996); Hyerle (1996) and Kessler (1995). The methods used to investigate this question also explored the issue of preferred learning styles (Kolb, 1984).
Chapter 4: Methodology-Overview of the three research studies

This study involved three linked research studies that complemented each other. During each study the methodology chosen was considered most appropriate for the research questions posed. In order to find examples of appropriate methodologies in recent studies, it was decided to search recent databases (ERIC, PsycLIT, Dissertation Abstracts from 1992 to 1995).

A search of these databases produced 134 different titles relating to the descriptors of "understanding or comprehending graphs" or "interpreting graphs". Of these only one was solely an empirical study that attempted to compare two sets of controlled conditions but the findings were too narrow to be of application to this study. The other 123 titles employed a mixture of methods such as survey, interview, audio recording, journal entries, video recording, and computer monitoring. While the findings from these studies were not generalisable to other contexts, collectively they identified factors that warranted further investigation. These studies guided the selection of many of the variables that were investigated.

A similar search involving the term "cognitive tools" (8 titles) showed that quantitative methods of analysis were employed in only one of these studies. This study employs both quantitative and qualitative research methods because it allowed the researcher to:

- use triangulation in order to seek a convergence of results;
- use complementary methods to identify overlapping and different facets of a phenomenon;
- use one method developmentally so as to inform the second method;
- bring multiple perspectives to the data;
- add scope and breadth to the study.

This chapter briefly describes three related and sequential studies that are the basis for this thesis and they are elaborated upon in Chapters 5, 6, and 7. Chapters 5, 6 and 7
elaborate further on the methods employed to gather and analyse data during each specific study. The annotated flow chart shown in Figure 4.1 provides an overview of the three sequential studies. Study 1 was designed to identify commonalities between previous studies and the preservice teachers used in this study and sought to identify and describe the cognitive strategies employed by preservice teachers as they interpreted graphs and tables. Study 2 applied the findings from Study 1 to develop a prototype of the cognitive tools that helped them make sense of data relating to rainforest destruction. Also Study 2 was designed to gather data about preservice teacher use of these cognitive tools. These data were then used to guide improvements that were made to the cognitive tools. During Study 3, the improved cognitive tools were then evaluated when they were used by the preservice teachers.

**Figure 4.1: An annotated flow chart of the three studies**
Figure 4.2 is a summary of the studies in schematic form. It serves to indicate when various data collection episodes occurred and when the various forms of the software were presented to preservice teachers.

Figure 4.2 Summary of the studies

Key

01 data from university database (gender, age, marks from senior high school and university studies in the English, Mathematics and Science, Computer studies, University Entrance Scores), responses to survey of previous experience with computers, plus learning style inventory responses (retest after a one month interval)

Subjects preservice teachers from Years 1 and 3

02 test on interpreting graphs and tables (retest after one month)

Subjects preservice teachers from Years 1, 3 and 4

03 attitude to computer questionnaire (retest after one month)

Subjects preservice teachers from Year 3 1995

X1 concept map tool.

Subjects preservice teachers from Year 3 1995

04 analysis of concept map 1.

Subjects preservice teachers from Year 3 1995

05 analysis of concept map 2, journal entries, and interviews.

Subjects preservice teachers from Year 3 1995

X2 prototype tool for interpreting graphs and tables.

Subjects preservice teachers from Year 3 1995
Study 1: Describing learner interpretation graphs and tables

All of the subjects who participated in Study 1 were volunteers and the composition of these groups is described in more detail in the next chapter. The subjects were drawn from three groups of preservice teachers: Year 1 (Freshmen), enrolled in a three year Bachelor of Teaching Degree in primary (elementary) school education; Year 3 (Junior), enrolled a three year Bachelor of Teaching Degree in primary school education, and Year 4 who were science graduates completing a one year Diploma of Education Degree in secondary science education.

Data relating to the previous academic experience of these subjects were also collected and details of the procedures involved are described in Chapter 5. A multiple choice test was administered to all subjects in order to measure their ability to read graphs (a copy of this test is shown in Appendix 2) and a description of how the forty-item multiple choice test was constructed occurs in Chapter 5 under the heading 'Study 1'.

The data from Study 1 were analysed to detect if any of the independent variables had affected the test scores. Any factors that could be addressed through the practical application of a system of cognitive tools were then identified and applied to the design of the final prototype.
Study 2: Development and evaluation of the prototype

Study 2 used the findings from Study 1 to guide the development of the prototype of cognitive tools designed to help them make sense of data relating to rainforest destruction. Furthermore, Study 2 gathered data about preservice teacher use these cognitive tools and these data were then used to further refine the cognitive tools.

The prototype of the cognitive tools was trialled with 63 preservice teachers enrolled in Year 3 of a Bachelor of Teaching Degree. This sample reflected the size and composition of the main group of subjects involved in Study 3. Interviews transcripts, journal entries and tracking data (consisting of a software generated summary file of the frequency and time subjects spent in viewing each individual screen of the program) were gathered and these data were used to provide information about preservice teacher use of the prototype of the cognitive tools. In particular, it was important to identify any difficulties they had with the tools and to gain an understanding of the cognitive strategies employed when they used the tools. These data were then used to further refine the cognitive tools.

Study 3: Researching use of the improved cognitive tools

Study 3 was designed to gather data about preservice teacher use of the improved cognitive tools and 80 preservice teachers enrolled in the third year of a Bachelor of Teaching (primary education) Degree used the improved cognitive tools. The data gathered included: individual concept maps created during the second and last weeks of the study; responses to an attitudes to computers questionnaire; interviews; and tracking data. It was expected that the data would indicate how successful the tools were and how they could be further modified. Details of how the data were analysed are discussed in Chapter 7.

A process of collaboration was used at each stage in the development process as it was important to understand how the cognitive tools employed were used to analyse and synthesise the information presented in the various forms of text, graphs and tables. The strategies which ensured effective collaboration were an important part of the research process and will be outlined in Chapter 7.
Chapter 5: Study 1- Learner background and strategies as factors affecting their ability to interpret graphs and tables

This study was designed to replicate and extend previous studies such as those of Janvier (1978) and Preece (1985). By applying interview and survey techniques, the researcher sought to identify common factors in learner backgrounds that affected their ability to interpret graphs and tables. Thus the aims of Study 1 were to:

- compare the ability of different groups of preservice teachers to interpret graphs and tables;
- identify factors that affected the ability of preservice teachers to interpret graphs and tables;
- identify and describe the cognitive strategies employed by preservice teachers when they interpreted graphs and tables.

Research questions and hypotheses

A discussion of the methods used to gather and analyse data associated with each research question follows.

Question 1. 1

What factors affect the ability of various groups of preservice teachers to interpret a set of graphs and tables?

Two approaches were taken to this question. The first approach was a quantitative approach that formulated and tested hypotheses that predicted relationships between independent and dependent variables. The second used a qualitative approach that relied upon interview data gathered from eight (7 - Year 1 and 1 - Year 4) preservice teachers after they completed the test of their ability to interpret graphs and tables.

The test was administered to Year 1, Year 3 and Year 4 preservice teachers. After the test was marked and the items analysed, seven questions were selected as items for the clinical interviews. The criteria for selection were varied degrees of difficulty, and varied
contexts that demanded a range of skills. Further details of this process are presented with the results in Chapter 5.

**Hypothesis 1.1.1**

Students who are enrolled in senior years in the BEd degree will be better at interpreting graphs and tables than those in junior years.

**Hypothesis 1.1.2**

Students who have completed an undergraduate science degree prior to commencing the teacher education program will be better at interpreting graphs and tables than those who have not completed such a degree.

The ability to interpret graphs and tables was measured by scores on a forty item multiple choice test designed to test these skills. ANOVA was then used to test for statistically significant difference in the test scores obtained by Year 1, Year 3 and Year 4 preservice teachers.

**Hypothesis 1.1.3**

The independent variables of gender, age, TER (Tertiary Entrance Rank), previous scores in English, Mathematics and Science tests, previous experience with computers and learning style are predictors of the scores obtained by preservice teacher subjects enrolled in Year 1 on the graphing and tables test (dependent variable).

The Year 1 group was used as a sample because it was a larger group and the whole year was available. Furthermore, most had completed senior secondary school in the previous year and the effects of maturation upon variables such as TER and previous scores and experience with computers would be less than in samples drawn from more senior years.

**Hypothesis 1.1.4**

Some of the independent variables (gender, age, TER, scores in English, Mathematics and Science tests, previous experience with computers and learning style) will serve as predictors of the other independent variables. In most cases this predictive relationship would be a positive one with higher scores in one variable predicting higher scores in the other variable.
Data from the Year 1 group was used and regression analysis was employed to test if there were any predictive relationships among variables. In most cases it was anticipated that the direction of any relationship would be positive. That is, the higher TER scores would be predictors of higher scores in Mathematics, but the reverse may be true for the relationship between age and TER as older students may be less familiar with the rigour of the external examination process associated with TER scores.

**Question 1.2**

What cognitive strategies do preservice teachers employ when they interpret graphs and tables?

Interviews were used to gather data about this question. Seven preservice teachers (who were volunteers from the Year 1 group) were interviewed about how they interpreted seven questions from the test. The seven questions selected contained a wide variety of graphs and tables and varied in the degree of difficulty. The questions focused on a variety of skills including comparing graphs and related tables, interpreting a table and relating it to text, interpreting a graph and relating it to text, comparing graphs presented in similar formats, comparing data tables. The preservice teacher who obtained the highest score on the test was also interviewed and one who obtained a low score was included in the group of seven mentioned previously.

**Question 1.3.**

How do the identified cognitive strategies compare with those strategies identified by other researchers?

The findings from research question 1.2 (the difficulties experienced and the strategies used by the seven preservice teachers interviewed) were compared with those of Janvier (1978) and Preece (1985) who are established researchers in the field.

**Methodology**

As this study sought to compare the ability of different groups of preservice teachers to interpret graphs and tables, a multiple-choice test, designed to measure preservice teacher ability to read graphs, was constructed and administered. A copy of this test is shown in Appendix 2. Scores on this test were used as a dependent variable to compare test
performances among the different groups of preservice teachers. Questionnaires and university enrolment information were also used to gather data about the independent variables (age, gender, marks from previous studies of English, Mathematics and Science, experience with computers and learning style). After all preservice teachers had completed the test, seven subjects were interviewed as they re-attempted seven of the questions from the original test. The data from these interviews were used to identify the cognitive strategies that the preservice teachers used when they were interpreting graphs and tables.

The preservice teachers were drawn from three groups: Year 1 who were enrolled in a three-year Bachelor of Teaching Degree in primary school education, Year 3 who were also enrolled in a three-year Bachelor of Teaching Degree in primary school education, and Year 4 who were science graduates completing a one-year Diploma of Education Degree in secondary science education. Table 5.1 shows the numbers in each group. The year indicates when the test, surveys and interviews were administered.

Table 5.1: Preservice teachers involved in Study 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Course</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 1994</td>
<td>B.Teaching (Primary)</td>
<td>132</td>
</tr>
<tr>
<td>3 - 1995</td>
<td>B.Teaching (Primary)</td>
<td>38</td>
</tr>
<tr>
<td>4 - 1995</td>
<td>Diploma of Education(Secondary Science)</td>
<td>19</td>
</tr>
</tbody>
</table>

Of similar studies reviewed the smallest sample was 15 (Linderblad, 1990), but most were between 40 and 200. The sample sizes chosen for this study are within the boundaries of typical studies in the field. While the sample characteristics and size would be similar to the intake of many similar sized universities in Australia, the findings may not necessarily be generaliserable to other institutions as the characteristics of the students enrolled will vary. However, it could form the basis of comparison studies or for a more extensive study across several institutions (assuming that the samples are carefully selected). Participation in the study was voluntary and students had the right to withdraw at any time. Primary teaching students were chosen as the main focus group because previous research (DEET, 1989: pp.23, 37) had shown that most students in pre-service primary
teacher education courses were low achievers in mathematics and science. Therefore it could be anticipated that many of this group of preservice teachers would experience difficulties in interpreting graphs and tables. The secondary science graduates were used as a comparison group who would be less likely to experience difficulties in interpreting graphs and tables.

**Mathematics and science backgrounds of the preservice primary teachers**

In 1992 only 66% of the first year preservice students enrolled in primary (elementary) teacher education courses had completed studies in mathematics subjects during senior high school. By 1993, 72% of first year students had completed studies in mathematics subjects during senior high school. This increase in senior high school completion rates can be attributed to changes in government policy which stated that by 1996 it would be mandatory for all teachers in New South Wales to have completed studies in senior secondary school mathematics.

Between 1992 and 1994, the results from screening tests administered to first year preservice teachers at this institution by Mathematics Educators showed that only prior experience with the more challenging examination subjects in senior high school (3 and 4 Unit Mathematics) were predictors of preservice teacher success in performance on screening tests in elementary school mathematics. Those who studied the less challenging senior mathematics subjects performed no better than those who did not study mathematics in senior secondary school (Crawford, 1995). Crawford (1995) concluded that the government legislation alone was unlikely to produce any improvement in the quality of mathematics education received by preservice teachers prior to their entry to university.

The situation in Primary Science Education was similar and enrolment data collected from first year preservice teachers enrolled in primary teacher education from 1991 to 1994 showed that while 12% of students had studied physical sciences (Physics and/or Chemistry), only 47% of the remaining group completed a science subject in senior secondary school.
Third year preservice teachers were selected as subjects for trials because the majority had successfully completed a compulsory subject in information technology and by the end of two years of study had used word processing software and drawing software for the preparation of some written assignments. Previous research (Summers, 1990; Wilson, 1990) found that a substantial proportion of students entering tertiary institutions to undertake teacher training have minimal previous experience with information technology. Furthermore, without adequate training, students in teacher education courses can develop misunderstandings and misconceptions about the technology and its applications. Thus the use of preservice students enrolled in the third year of their degree controlled to some extent the variable of computer expertise as the majority of students would at the very least be familiar with Apple Macintosh™ computers used in the study and they would also be familiar with HyperCard™ presentation of learning materials. However, it does not necessarily follow that all students who successfully complete information technology subjects will feel confident with computers (Haywood & Norman, 1988; Novak & Knowles, 1991).

Preservice teacher access to computers could be an important factor in how well they use them. A study of factors influencing teacher uptake of computers by Oliver (1994) found that access to computers was an important factor. Moreover, Oliver found that it wasn't just the access to the hardware that was important but also the access to quality "user friendly" software that could assist the teacher to perform the task required. During the present study this factor was controlled to some extent through the use of a questionnaire which asked the subjects about their use of and access to computers. The responses were allocated into two different categories based upon the subjects' formal training with computing, access to computers and use of computer software. For example subjects who completed a formal subject in information technology, had frequent access to a computer and frequently used application programs like word processing, data bases and spreadsheets were categorised as experienced users of computers. Those who had not completed a formal subject, had little if any access to computers, and made little if any use of application software were considered novice users. It was expected that in the context of this study very few of the subjects would be novice users and most would be experienced users of computers. However, it needs to
be acknowledged that a person who states that they are an experienced user may not necessarily feel at ease when they use them.

**Variables investigated in this study**

The variables included were selected after an extensive review of the literature. The independent variables selected for this study were: age, gender, marks from previous studies in English, Mathematics and Science, experience with computers and learning style. They were chosen so that the data could contribute to existing and further research in related fields.

Gender and age were included because the findings from research suggested that these factors could relate to the ability of subjects to interpret graphs and tables in text (MacDonald-Ross, 1977; van Reeuwijk, 1992). Research by Mosenthal and Kirsh (1991) showed that the ability to read and interpret graphs was influenced by the levels of English literacy attained by subjects. The text associated with graphs and tables identified key terms and concepts and described the context. Therefore the text needed to be understood as well as the graph or table.

Bowen (1992) claimed that "to read a graph is to state the relationship that is present, to describe the relationship that is present, and to analyse the slope of the data curve. To interpret a graph is to determine the significance of the data relationship that is present, including the causes of the relationship and the implications of it" (p. 63). His work suggests that mathematics achievement may also be a factor that affects the ability to interpret graphs and tables. Finally science achievement was included as a factor as the graphs chosen for the test were related to the interpretation of scientific data. The data relating to science achievement were likely to be diverse as there were eight different subjects on offer for senior high school students in New South Wales. As a result, the numbers in the science subjects may be too small to be used in statistical comparisons. Instead aggregated science achievement data were used as students of senior high school science can be expected to have developed skills in interpreting graphs and tables (Curriculum Corporation, 1994).

Finally, experience with computers was considered as a factor because the task required them to use a Macintosh™ computer. However, it was considered likely that most
subjects who used the software developed for this study would be capable users of computers as they had successfully completed a one semester subject in information technology. The subject outline in the University of Wollongong Calendar Undergraduate (1995, p. 402-403) states that students enrolled in the subject can expect to become familiar with the Macintosh™ user interface and "a range of application packages such as word processing, drawing, databases, and communication packages...as well as studying a range of commercially available educational software and application software such as HyperCard™, CD-ROM and interactive multimedia."

The marks from previous studies included: the most recent final marks from the preservice teacher degree course in Language (English), Mathematics, Science and Information Technology subjects, as well as subject marks gained from an externally set senior high school examination or its equivalent. In New South Wales this examination is called the Higher School Certificate, and the number of preservice teachers who had completed this examination was 101 or 78%. Preservice teachers who did not complete their secondary education in NSW or Australia were included in the sample if the university enrolment centre allocated a mark (based upon a comparable test) for one or more of the above subjects. University entrance records were the source of this information.

The tertiary entrance rank (TER) of each subject was also obtained from the enrolment records. The TER is a percentile ranking based upon an aggregation of scores students obtain in the Higher School Certificate in New South Wales. The procedure is conducted by the University of Sydney for the New South Wales Department of School Education and has been used for over 15 years as a selection procedure for university entrance. All preservice teachers who enter university from other states, from overseas and as mature age students are also allocated a tertiary entrance score by the university. Twenty nine students were in this category.

Preferred learning styles were determined using Kolb's learning style inventory and a full discussion of Kolb's instrument occurs in Chapter 2. If the cognitive processes that learners use to interpret graphs and tables vary, then the variable of preferred learning style should be investigated because there may be a relationship between preferred learning style and the way in which learners process the information presented.
Kolb's inventory is based upon an information processing model of learning that involves experiential learning (Kolb et al., 1974). It applies to adults and is suited to university students (De Bello, 1990). Other research (Certo and Lamb, 1980; Freedman and Stumpf, 1981) concluded that the instrument was well suited for learning about an individual's learning style but questioned its reliability when used for comparisons across groups. Other inventories such as the learning style inventory, originally designed by Dunn, Dunn and Price (1979) were considered because they had higher reliability and validity statistics, but often they contained up to 100 items and were oriented toward use in secondary schools. The Kolb instrument was simpler and easier to use. Therefore, the final choice was based on a compromise between the factors of reliability and validity, ease of use, applicability to the target group, and the relationship of the underlying model of learning associated with the inventory and the context of this study.

Measuring learner ability to interpret graphs and tables

The dependent variable was the score that the subjects received on the instrument designed to test their ability to interpret graphs. This score was a mark out of a total of forty obtained from a multiple choice test. The test items were selected from an item bank used in the Australian Schools Science Competition from 1988 to 1994, a copy of which appears in the Appendix. Items were chosen from test papers designed to test students in Year 10 (16 years old). Year 10 is the final year of compulsory science for most secondary school students and it was assumed that most subjects would have been exposed to the language and concepts involved in these questions. The level of difficulty was considered by staff at the Education Testing Centre of the University of New South Wales to be challenging (Wang, April 15th, 1995, personal communication), especially with respect to physical science as only 14.8% of the subjects in this study had studied physical sciences at senior high school. These results are similar to the figures quoted by the Discipline Review of Teacher Education in Mathematics and Science which found that only 14 percent of pre-service primary teachers had studied physical science in senior high school (DEET, 1989, p.37).

The skills needed to successfully process these test items were identified and categorised using data supplied by the Education Testing Centre of the University of New South Wales. A grid of the skills (see Appendix 6) to be tested was constructed and the items
distributed so that the skills identified were tested by the same number of items. All items selected were validated by the staff from the Education Testing Centre of the University of New South Wales (Wang, April 15th, 1995 person communication).

**Analysis of graphs and tables test**

ANOVA was used to compare the three groups who completed the test and regression analysis was used with each group to ascertain if there was any significant relationship between the dependent variable (subject scores on the test for interpreting graphs and tables) and the independent variables of: gender; age; previous scores in English; Mathematics and Science tests; previous experience with computers; and learning style.

**Results - Study 1**

The total test score (out of forty) was obtained for each preservice teacher and calculated by adding the total number of correct responses for the forty item graphs and tables test. The scores for the main group (first year preservice teachers) were compared with those enrolled in the third year of the same degree, and with science graduates enrolled in a Diploma of Education (Secondary Science). After two months each group was given a retest and the correlations between scores were: Year 1, .74; Year 3, .77; Year 4, .82. Thus the reliability of the test was acceptable (Oppenheim, 1992, p. 129).

**Investigation of Hypotheses 1.1.1 and 1.1.2**

One-way ANOVA was to used compare test scores among the first year, third year preservice teachers and the science graduates. The results of this analysis, reported in table 5.2, show that there was a significant difference between the scores of the science graduates and the other preservice teachers, but the difference between Year 1 and Year 3 students enrolled in the Bachelor of Teaching (Primary) did not approach significance. Therefore hypothesis 1.1.1 was not supported and hypothesis 1.1.2 was supported.
Table 5.2: One way ANOVA analysis of year - course enrolment and test scores

One Factor ANOVA $X_1$: Year $Y_1$: Scores /40

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum Squares</th>
<th>Mean Square</th>
<th>F-test:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>4330.1</td>
<td>2165</td>
<td>98.2</td>
</tr>
<tr>
<td>Within groups</td>
<td>186</td>
<td>4098.7</td>
<td>22</td>
<td>p = .0001</td>
</tr>
<tr>
<td>Total</td>
<td>188</td>
<td>8428.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model II estimate of between component variance = 49.1

One Factor ANOVA $X_1$: Year $Y_1$: Scores /40

<table>
<thead>
<tr>
<th>Group</th>
<th>Count</th>
<th>Mean:</th>
<th>Std. Dev.:</th>
<th>Std. Error:</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>132</td>
<td>17.2</td>
<td>5.2</td>
<td>.5</td>
</tr>
<tr>
<td>Three</td>
<td>38</td>
<td>18.1</td>
<td>3.4</td>
<td>.5</td>
</tr>
<tr>
<td>Dip Ed</td>
<td>19</td>
<td>33.3</td>
<td>2.6</td>
<td>.6</td>
</tr>
</tbody>
</table>

One Factor ANOVA $X_1$: Year $Y_1$: Scores /40

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Mean Diff.:</th>
<th>Fisher PLSD:</th>
<th>Scheffe F-test:</th>
<th>Dunnett t:</th>
</tr>
</thead>
<tbody>
<tr>
<td>One vs. Three</td>
<td>-.9</td>
<td>1.7</td>
<td>.5</td>
<td>1</td>
</tr>
<tr>
<td>One vs. Dip Ed</td>
<td>-16.1</td>
<td>2.3*</td>
<td>97.4*</td>
<td>14</td>
</tr>
<tr>
<td>Three vs. Dip Ed</td>
<td>-15.2</td>
<td>2.6*</td>
<td>66.3*</td>
<td>11.5</td>
</tr>
</tbody>
</table>

* Significant at 95%

The similarity of scores between the Year 1 and Year 3 undergraduates may indicate that the skills needed to interpret graphs and tables are not emphasised in their academic subjects. Examination of the subject descriptions in the University of Wollongong Undergraduate Handbook for 1995 (pp. 390-420) showed that there was no direct reference to skills associated with the interpretation graphs and tables. The subject coordinators of Language (English), Mathematics, Science and Information Technology (April, 1995) were interviewed and they reported that such skills were not emphasised.
and curriculum and pedagogical knowledge and skills were considered more important at this stage of the undergraduates' development. Multiple regression analysis of the Year 3 data gathered from university files for the above subjects showed that there was no significant relationship between scores in the university subjects of Language (English), Mathematics, Science and Information Technology and test scores for interpreting graphs and tables (F(3,62)=.7, p=.56).

The first year group (enrolled in 1994) formed the focus for the remainder of the data presented as they represent all the preservice teachers in their year. Also many of these preservice teachers used the final version of the cognitive tools when they were enrolled in Year 3 (1996).

**Data from the first year preservice teachers**

Table 5.3 displays a summary of relevant data for the first year group. The acronym Tertiary Entrance Rank (TER) is a percentile rank based upon student scores in a state wide external examination called the New South Wales Higher School Certificate. One hundred and one preservice teachers completed the Higher School Certificate, and obtained a TER. The other 31 preservice teachers who did not sit for a Higher School Certificate examination were awarded a TER rank that was based upon university entrance examinations.

<table>
<thead>
<tr>
<th>Age</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tertiary Entrance Rank</td>
<td>67.6</td>
<td>13.2</td>
<td>99.6</td>
<td>42.1</td>
</tr>
</tbody>
</table>

Table 5.3: Data about the subjects (N= 132; 115 female and 17 male)

The mean TER for preservice teachers was 67.6 and this rank is comparable with other institutions enrolling first year preservice teachers studying similar courses in New South Wales (Lewis, 1994.)

Table 5.4 lists the number of first year preservice teachers who completed English, Mathematics and Science subjects for the Higher School Certificate. This data was obtained (with student permission) from official enrolment data. The table shows that all completed the compulsory English subject; 73% percent studied Mathematics in senior high school, 68% studied Science and 16% studied Computer Studies. No student
studied 4 units of Mathematics or 4 units of Science. These subjects were academically more demanding.

Table 5.4: Previous study completed at senior high school (N=101)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Number of persons</th>
<th>Percentage of total N=101</th>
<th>Mean Score</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Unit English</td>
<td>1</td>
<td>1</td>
<td>66.8</td>
<td>8.2</td>
</tr>
<tr>
<td>2 Unit English</td>
<td>100</td>
<td>100</td>
<td>81.6</td>
<td>8</td>
</tr>
<tr>
<td>TOTAL ENGLISH</td>
<td>101</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Unit Maths</td>
<td>10</td>
<td>9.9</td>
<td>66.7</td>
<td>4.2</td>
</tr>
<tr>
<td>2 Unit Maths</td>
<td>63</td>
<td>62.4</td>
<td>71.5</td>
<td>10.4</td>
</tr>
<tr>
<td>TOTAL MATHS</td>
<td>73</td>
<td>72.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemistry*</td>
<td>12</td>
<td>11.9</td>
<td>57.3</td>
<td>7.3</td>
</tr>
<tr>
<td>Physics*</td>
<td>3</td>
<td>2.9</td>
<td>66.7</td>
<td>4.2</td>
</tr>
<tr>
<td>Biology*</td>
<td>46</td>
<td>45.5</td>
<td>67.9</td>
<td>10.3</td>
</tr>
<tr>
<td>Other science</td>
<td>8</td>
<td>7.9</td>
<td>79</td>
<td>7.3</td>
</tr>
<tr>
<td>TOTAL SCIENCE</td>
<td>66</td>
<td>65%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer studies</td>
<td>16</td>
<td>15.8</td>
<td>70.2</td>
<td>7.4</td>
</tr>
</tbody>
</table>

* These subjects are not necessarily mutually exclusive but in this case only three students were within two or more categories (e.g., the three students who studied Physics also studied Chemistry). Thus the total number of students who studied at least one science subject was 66.

Investigation of Hypothesis 1.1.3

Stepwise regression analysis was used to determine if there was any significant relationship between the independent variables of gender, age, TER, and subject results in English, Biology and Mathematics and the dependent variable of test score obtained.

Science scores other than biology were aggregated but no significant relationship was obtained.

Table 5.5 shows that two-unit Maths scores were significant (F(1,34) = 6.1, p = .01, \( r^2 = .2 \)), and the positive slope of the regression equation indicated that higher 2 Unit Mathematics scores were a predictor of higher graphing and table scores. The data also indicated that 20% of the observed variation in test scores could be attributed to 2 unit Maths scores. Table 5.5 summarises the results of this analysis.
Table 5.5: Stepwise regression of the independent variables of gender, age, TER, Mathematics, Biology and English scores, and the dependent variable test scores

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Err.</th>
<th>Std. Coeff.</th>
<th>F to Remove</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>4.5</td>
<td>.1</td>
<td>.4</td>
<td>6.1</td>
</tr>
<tr>
<td>2UMathsMk</td>
<td>.2</td>
<td>.1</td>
<td>.4</td>
<td>6.1</td>
</tr>
</tbody>
</table>

Variables Not in Equation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Par. Corr.</th>
<th>F to Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.1E-2</td>
<td>4.0E-3</td>
</tr>
<tr>
<td>TER</td>
<td>.1</td>
<td>.1</td>
</tr>
<tr>
<td>G</td>
<td>.1</td>
<td>.5</td>
</tr>
<tr>
<td>2UE</td>
<td>.1</td>
<td>.4</td>
</tr>
<tr>
<td>Bi</td>
<td>.1</td>
<td>.7</td>
</tr>
</tbody>
</table>

Key:
G=Gender, 2UE= 2Unit English, Bi=Biology

Thus 2 Unit Mathematics scores were the only variable that served to predict preservice teacher ability to interpret graphs and tables and this could account for 20% of the variation of the test scores. Further detailed investigation of this variable is warranted as there may be specific features of this mathematics subject that enhance learner ability to interpret graphs and tables.

ANOVA was used to determine if there was any significant relationship between preferred learning style and test scores but no significant relationship was found (F(3, 132)=.74, p=.6).

Investigating Hypothesis 1.1.4

Only two of the independent variables were related: age and TER. Simple regression analysis showed that there was a significant relationship between age and TER (F(1,132)
=6.6, \( p=.01, r^2 =.04 \), and 4% of the variation in TER could be attributed to age. The negative slope of the regression equation suggests that older preservice teachers tended to score lower TERs than younger preservice teachers. It could be argued that this is related to how the mature age students are scored for their TER; however the findings of Lewis (1994) do not support this interpretation. His research indicates that university entrance standards for mature age students across all faculties are equal to if not better than those who enter directly from high school, but data in his study did not specifically relate to the sample involved in this study. Therefore, it would be useful to follow up this study with similar samples from other universities as it may be that the abilities of the mature age students enrolled in education faculties differ from those in other faculties.

**The interviews with the seven preservice teachers**

In addition to the quantitative results, seven preservice teachers (who were volunteers from the Year 1 group) were interviewed about how they interpreted seven questions from the test. The seven questions selected contained a wide variety of graphs and tables and varied in the degree of difficulty. The easiest questions were correctly answered by 94% of preservice teachers in Year 1 and the most difficult question chosen was correctly answered by 44% of preservice teachers in Year 1. The order in which the questions were presented was consistent. The first question was used as a "warm up" question so that the preservice teacher could become engaged with the task. The second question was the easiest question presented and was deliberately placed in this position in order to build subject self-confidence.

Table 5.6 displays information about the questions chosen for interviews. The column labelled "% correct" refers to the percentage of preservice teachers who correctly answered the questions in the test.
Table 5.6: Details of the questions chosen for interviews

<table>
<thead>
<tr>
<th>Features of questions chosen for interviews</th>
<th>Test question</th>
<th>% correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. comparison of a line graph and a column graph</td>
<td>1</td>
<td>53</td>
</tr>
<tr>
<td>2. interpreting a table</td>
<td>2</td>
<td>94</td>
</tr>
<tr>
<td>3. interpreting a curve, determining relative gradient of sections of the graph</td>
<td>3</td>
<td>63</td>
</tr>
<tr>
<td>4. comparing two pie graphs</td>
<td>6</td>
<td>57</td>
</tr>
<tr>
<td>5. comparing data from table and line graphs</td>
<td>18</td>
<td>73</td>
</tr>
<tr>
<td>6. choosing a bar graph that describes a labelled chart</td>
<td>20</td>
<td>91</td>
</tr>
<tr>
<td>7. choosing a histogram that relates to a specified context</td>
<td>28</td>
<td>44</td>
</tr>
</tbody>
</table>

Interview procedure for interpreting graphs and tables

The following procedure was followed for each audio-taped interview.

1. As each preservice teacher read a question and selected their answer, the researcher made observation notes. To simplify observation, each preservice teacher was asked to point to each section of the text, table or graph as they read it.

2. After selecting an answer for a question, each preservice teacher described how they used the information to obtain their answer.

3. Follow-up questions were used to clarify details. Some of these questions were based on the observation notes.

4. Finally the subjects were asked to add any additional comments.

Steps 1 to 4 were repeated for each question.

Recorded interviews were transcribed, analysed and coded. The process was iterative and involved a computer-aided search of transcripts and the marking of key words and phrases, writing narrative summaries that drew attention to the key words and phrases, coding of key words and phrases.

The final list of coded actions that were identified by this process is listed below:

1. the preservice teacher paid attention to global features of the graph(s) eg. rises/falls; slope; plateaux;
2. the preservice teacher paid attention to local features of the graph(s) eg. labels on axes, labels attached to graphs;

3. the preservice teacher paid attention to local features of the table eg. column labels; row labels, specific values;

4. the preservice teacher read all or part of the question;

5. the preservice teacher compared alternative answers.

These coded actions were used as headings for columns of a table. As the interview transcripts and researcher notes were re-analysed for each question, sections were coded and then numbered in sequential order. These numbers were entered as shown in table 5.7 below.

**Table 5.7: How the interview transcripts were coded**

<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Age</th>
<th>Action</th>
<th>Viewed global feature graph</th>
<th>Viewed local feature graph</th>
<th>Viewed local feature table</th>
<th>Read question</th>
<th>Compared answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fred</td>
<td>M</td>
<td>23</td>
<td>Order</td>
<td>3</td>
<td>4</td>
<td></td>
<td>1</td>
<td>2,5</td>
</tr>
</tbody>
</table>

**Interpretation of table**

Fred read the question first (order 1); then he compared answers (order 2). He then looked at the global features of the graph (order 3) before he looked at the local features of the graph (order 4). Finally, he went back to the questions (order 5) to choose his answer. The preservice teachers were told to take their time as the researcher was interested in how they interpreted the questions rather than how long they took. Also if they sensed that time was a factor then, the interviewees may have become anxious about the procedure.

**Summary of data from interviews**

The interview data is presented in the same order as the questions were given to the preservice teachers. Summary tables are followed by brief comments and two excerpts from interview transcripts.
Interview Question 1 (Test Question 1- interpreting a graph)

Table 5.8 displays data from the observations of preservice teachers as they attempt to answer question 1.

Table 5.8: Data analysis for Question 1

<table>
<thead>
<tr>
<th>Subject name</th>
<th>G</th>
<th>Age</th>
<th>Viewed global feature graph</th>
<th>Viewed local feature graph</th>
<th>Viewed local feature table</th>
<th>Read question</th>
<th>Compared answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharon, correct</td>
<td>F</td>
<td>34</td>
<td>1, 4</td>
<td>6, 7</td>
<td></td>
<td>2</td>
<td>3, 5, 8</td>
</tr>
<tr>
<td>Alison, correct</td>
<td>F</td>
<td>20</td>
<td>2, 4, 6</td>
<td>7</td>
<td></td>
<td>1, 8</td>
<td>3, 5, 9</td>
</tr>
<tr>
<td>Anne, correct</td>
<td>F</td>
<td>39</td>
<td>3, 7, 9</td>
<td>2, 6</td>
<td></td>
<td>1, 5</td>
<td>4, 8</td>
</tr>
<tr>
<td>Ellon, incorrect</td>
<td>F</td>
<td>48</td>
<td>1</td>
<td>2, 6</td>
<td></td>
<td>3, 5</td>
<td>4, 7</td>
</tr>
<tr>
<td>Linda, correct</td>
<td>F</td>
<td>28</td>
<td>2, 7</td>
<td>3, 5, 8</td>
<td></td>
<td>1</td>
<td>4, 6</td>
</tr>
<tr>
<td>Monica, correct</td>
<td>F</td>
<td>42</td>
<td>3, 6</td>
<td>2, 4, 7</td>
<td></td>
<td>1</td>
<td>5, 8</td>
</tr>
<tr>
<td>Grant, correct</td>
<td>M</td>
<td>30</td>
<td>3, 5</td>
<td>4, 7</td>
<td></td>
<td>1</td>
<td>2, 6, 8</td>
</tr>
</tbody>
</table>

Comments. The starting point was either the question or the global features of the graph. Those who chose the correct answer looked at the global features of the graph on more than one occasion.

The interview transcripts that follow show that the descriptions given by the preservice teachers were close to what was observed. Note that the labelling of the x-axis confused them because it began with July instead of January.

Sharon

I looked at the highest temperatures and tried to put it across to the groups in the next graph. I looked at the axes (vertical) to see which temperature range they prefer (Looks at answers). Because it's giving me multiple choice answers I try to work it out before I look at the answers. A verbal description of the graph is given....At first the answers didn't seem to fit the graph. Later I realised that I should read the left hand axes instead of the bottom one.

I was using my fingers to try to juggle the labels on the bottom because I wasn't used to these labels. You got to mentally go through the calendar to find out how the months are labelled.

Ellon

I referred to the graphs and I tried to formulate an answer before I looked at the question properly. I looked at the ups and downs and found the highest point. Then I found the month (points to x-axis). These (pointing at the months) are out of order, I wasn't sure of the letters meant - I thought that the J label had to be January it didn't occur to me that it was July until now...I should have looked again.
Table 5.9 displays data from the observations of preservice teachers as they attempt to answer question 2 which related to the interpretation of tables.

**Table 5.9: Data analysis for Question 2**

<table>
<thead>
<tr>
<th>Subject name</th>
<th>G</th>
<th>Age</th>
<th>Viewed global feature graph</th>
<th>Viewed local feature graph</th>
<th>Read questions</th>
<th>Compared answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharon, correct</td>
<td>F</td>
<td>34</td>
<td></td>
<td>2,4,6</td>
<td>1, 3</td>
<td>5, 7</td>
</tr>
<tr>
<td>Alison, correct</td>
<td>F</td>
<td>20</td>
<td></td>
<td>3,5,7, 9</td>
<td>1</td>
<td>2,4, 6,8</td>
</tr>
<tr>
<td>Anne, correct</td>
<td>F</td>
<td>39</td>
<td></td>
<td>2,4, 6,8</td>
<td>1</td>
<td>3, 5,7,9</td>
</tr>
<tr>
<td>Ellon, incorrect</td>
<td>F</td>
<td>48</td>
<td></td>
<td>2</td>
<td>1,4</td>
<td>3</td>
</tr>
<tr>
<td>Linda, correct</td>
<td>F</td>
<td>28</td>
<td></td>
<td>1,4,6,8,10</td>
<td>2</td>
<td>3,5,7,9,11</td>
</tr>
<tr>
<td>Monica, incorrect</td>
<td>F</td>
<td>42</td>
<td></td>
<td>3,5,7,9</td>
<td>1</td>
<td>2,4,6,8</td>
</tr>
<tr>
<td>Grant, correct</td>
<td>M</td>
<td>30</td>
<td></td>
<td>2,4,6</td>
<td>1</td>
<td>3,5,7</td>
</tr>
</tbody>
</table>

Comments. Most read the question first and moved back and forth comparing answers with the tables. The exception was Ellon who became confused and asked for help. Linda also had problems with this question; her action summary shows that she spent time trying to relate the table to the answers. The transcripts illustrate the problem of cognitive load associated with this question.

Sharon

The options didn't fit any of my alternatives until I got to the last column. I eliminated each one as I went along...You had to keep storing the information as you went through the five sections to compare it.

Alison

I read the question then looked at the answers and kept going back to the table to test the answers. I thought that C looked right but even though it didn't work, I kept coming back to it and in the end I chose it...I couldn't match so I had to try and keep the information in my head. I had trouble keeping the information in my head because none of the bits were near each other (no columns were sorted).

**Interview Question 3 (Test question 3 - interpreting a gradient)**

Table 5.10 displays data from the observations of preservice teachers as they attempt to answer question 3 which related to the interpretation of a gradient.
Table 5.10: Data analysis for Question 3

<table>
<thead>
<tr>
<th>Subject name</th>
<th>G/Age</th>
<th>Viewed global feature graph</th>
<th>Viewed local feature graph</th>
<th>Viewed local feature table</th>
<th>Read question</th>
<th>Compared alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharon, correct</td>
<td>F/34</td>
<td>1.6</td>
<td>2, 4</td>
<td></td>
<td>3, 5</td>
<td>7</td>
</tr>
<tr>
<td>Alison, correct</td>
<td>F/20</td>
<td>1</td>
<td>3.5</td>
<td>7</td>
<td>2</td>
<td>4, 6, 8</td>
</tr>
<tr>
<td>Ann, correct</td>
<td>F/39</td>
<td>3.5</td>
<td>2.6</td>
<td></td>
<td>4, 7</td>
<td>1</td>
</tr>
<tr>
<td>Ellon, incorrect</td>
<td>F/48</td>
<td>2</td>
<td>3</td>
<td></td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Linda, incorrect</td>
<td>F/28</td>
<td>2</td>
<td>4</td>
<td></td>
<td>1</td>
<td>3, 5</td>
</tr>
<tr>
<td>Monica, correct</td>
<td>F/42</td>
<td>1.3</td>
<td>5</td>
<td></td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Grant, correct</td>
<td>M/30</td>
<td>2.4</td>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Comments. This question focused upon the interpretation of a gradient. Therefore, those who were familiar with gradients should have found this question easy. The dialogue with Linda illustrates how she could succeed after a little prompting.

Anne

Well I read the questions first and then I looked at both lines on the side of the graph, the year (x-axis) and the number of known elements (y-axis), and (pause) then I looked at how the graph went - it went flat then up very steep ...and then I looked at the actual answers. By looking at the graph and finding where the greatest rises and shortest falls were in the years I found the answer.

Linda

When I did it I read the question and then looked at the graph and found where the most elements were from the left side (y-axis). This was after 1900...so I decided that D was the answer.

Researcher

Let's explore this a little more. If you look at the question it asks you about the greatest number of elements discovered between certain dates. What does this mean?

Linda

Ah... it should be here (points to greatest slope).

Researcher

Why did you point there Linda?

Linda

Because this is where the greatest rise in the graph is... so that was the biggest rise.

Interview Question 4 (Test question 6 - comparing pie charts)

Table 5.11 displays data from the observations of preservice teachers as they attempt to answer question 4 which related to the comparison of pie charts.
Table 5.11: Analysis of data from Question 4

<table>
<thead>
<tr>
<th>Subject name</th>
<th>G</th>
<th>Age</th>
<th>Viewed global feature graph</th>
<th>Viewed local feature graph</th>
<th>Viewed local feature table</th>
<th>Read question</th>
<th>Compared alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharon, correct</td>
<td>F</td>
<td>34</td>
<td>1</td>
<td>3</td>
<td></td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Alison, incorrect</td>
<td>F</td>
<td>20</td>
<td>1</td>
<td>2, 5, 7, 9</td>
<td></td>
<td>3</td>
<td>4, 6, 8, 10</td>
</tr>
<tr>
<td>Anne, incorrect</td>
<td>F</td>
<td>39</td>
<td>2</td>
<td>4, 6</td>
<td></td>
<td>1</td>
<td>3, 5, 7</td>
</tr>
<tr>
<td>Ellon, correct</td>
<td>F</td>
<td>48</td>
<td>1, 3</td>
<td>4, 6</td>
<td></td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Linda, correct</td>
<td>F</td>
<td>28</td>
<td>2</td>
<td>4, 6</td>
<td></td>
<td>1</td>
<td>3, 5, 7</td>
</tr>
<tr>
<td>Monica, correct</td>
<td>F</td>
<td>42</td>
<td>4, 6</td>
<td>5, 7</td>
<td></td>
<td>1, 3</td>
<td>2</td>
</tr>
<tr>
<td>Grant, correct</td>
<td>M</td>
<td>30</td>
<td>2, 4, 7</td>
<td>3, 6</td>
<td></td>
<td>1, 5</td>
<td>8</td>
</tr>
</tbody>
</table>

Comments. The transcripts show how important it was to carefully read the local features of the graphs, and the analysis table (column 4) shows that all subjects focused on this part of the graphs. In Anne's case the most prominent local feature actually distracted her attention. Ellon appeared to use mathematics and a process of elimination.

Anne
I read the question, and then I had a quick look at the outside part here. The middle part confused me and I didn't look at that at all. I then looked at the outside part (pie chart) and began a process of elimination to find the right answer. Straight away I went to the remote houses (most prominent global feature) and thought that something that got that in it has to be in one of the answers. Then I have to choose between B and C (at this point she was confused).

Researcher
Did you try comparing the numbers in each pie chart?

Anne
No ... I can see that I really guessed this and didn't take notice of the numbers.

Ellon
I read the graphs first and was confused so I tried the question. I could work out how to compare them because they looked different...then I noticed that the numbers were there so I tried subtracting the numbers to find the difference and I could then get the answer.

Interview Question 5 (Test question 18 - comparing different types of graphs with a table)

Table 5.12 displays data from the observations of preservice teachers as they attempt to answer question 5 which related to comparing different types of graphs with a table.
Table 5.12: Analysis of data from Question 5

<table>
<thead>
<tr>
<th>Subject name</th>
<th>G</th>
<th>Age</th>
<th>Viewed global feature graph</th>
<th>Viewed local feature graph</th>
<th>Viewed local feature table</th>
<th>Read question</th>
<th>Compared alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharon, correct</td>
<td>F</td>
<td>34</td>
<td>3</td>
<td>1,2</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Alison, correct</td>
<td>F</td>
<td>20</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Anne, correct</td>
<td>F</td>
<td>39</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>4,6</td>
</tr>
<tr>
<td>Ellon, incorrect</td>
<td>F</td>
<td>48</td>
<td>3, 5, 7</td>
<td>4,6</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Linda, correct</td>
<td>F</td>
<td>28</td>
<td>2</td>
<td>5</td>
<td>4,6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Monica, incorrect</td>
<td>F</td>
<td>42</td>
<td>3</td>
<td></td>
<td>4</td>
<td>1</td>
<td>2,5</td>
</tr>
<tr>
<td>Grant, correct</td>
<td>M</td>
<td>30</td>
<td>1</td>
<td>3,6</td>
<td>2</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Comments. The analysis table shows that it was important to carefully read the local features of the graph and relate it to the table. The transcripts below further illustrate this point.

Anne

I started by reading the question. I had a glimpse of the temperature of the lizard (table) to get a rough idea of the rise and fall. Then I noticed that there were three temperatures there that were all the same and there has to be a flat part on the graph somewhere. So it comes down to those two graphs there. And by tracing it and checking with the table I came up with C.

Yeah ... the way I did... again the swirly line caught my attention first, but I looked at the table and analysed the information there and tried to correlate that to the line. The 36, 36, 36 values stuck in my mind and when I found that part on the graph I knew that I'd found the answer. That was the key thing that stood out and I knew that I was looking for a flat section.
**Interview Question 6 (Test question 20 - relating a graph to chart)**

Table 5.13 displays data from the observations of preservice teachers as they attempt to answer question 6 which related a graph to a chart.

**Table 5.13: Analysis of data from Question 6**

<table>
<thead>
<tr>
<th>Subject name</th>
<th>G</th>
<th>Age</th>
<th>Viewed global feature graph</th>
<th>Viewed local feature graph</th>
<th>Viewed local feature table</th>
<th>Read question</th>
<th>Compared alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharon, correct</td>
<td>F</td>
<td>34</td>
<td>2</td>
<td>4</td>
<td></td>
<td>1</td>
<td>3,5</td>
</tr>
<tr>
<td>Alison, incorrect</td>
<td>F</td>
<td>20</td>
<td>2, 4</td>
<td></td>
<td></td>
<td>1</td>
<td>3, 5</td>
</tr>
<tr>
<td>Anne, incorrect</td>
<td>F</td>
<td>39</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Ellon, incorrect</td>
<td>F</td>
<td>48</td>
<td>2</td>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Linda, correct</td>
<td>F</td>
<td>28</td>
<td>2</td>
<td>3, 5</td>
<td></td>
<td>1</td>
<td>4, 6</td>
</tr>
<tr>
<td>Monica, incorrect</td>
<td>F</td>
<td>42</td>
<td>2</td>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Grant, correct</td>
<td>M</td>
<td>30</td>
<td>2</td>
<td>3, 5</td>
<td></td>
<td>1</td>
<td>4, 6</td>
</tr>
</tbody>
</table>

**Comments.** The interview transcripts and the data table show that again those who succeeded read the local features (axis labels).

Alison

I was looking at the pictures ... just something didn't click for me ... and I was trying to figure it out. I knew it had to go down but I couldn't see which one (graph) went down by 25%. I just ruled the bottom two out because they were going the wrong way. I thought that B looked more even and must be right but now I realise that A is right because it goes down by 15% at the start (points to left hand axis).

Researcher

Did you look at the label on the left hand side when you answered the question?

Alison

No, no. The pictures were a little confusing as there wasn't much difference in the last two.

Ellon

I looked at the picture and went to the graphs and I went for B, but now I look it again and read the question (I didn't read it before). There is a big difference between the sizes.

Researcher

Tell me how you made your first choice.

Ellon

I just knew that it was a decreasing scale and chose the one that went down in even steps...I was a bit careless.
**Interview Question 7 (Test question 28 - relating graph to context)**

Table 5.14 displays data from the observations of preservice teachers as they attempt to answer question 7 which relates a graph to its context.

**Table 5.14: Analysis of data from Question 7**

<table>
<thead>
<tr>
<th>Subject name</th>
<th>G</th>
<th>Age</th>
<th>Viewed global feature graph</th>
<th>Viewed local feature graph</th>
<th>Viewed local feature table</th>
<th>Read question</th>
<th>Compared alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharon, correct</td>
<td>F</td>
<td>34</td>
<td>3</td>
<td>5,7</td>
<td></td>
<td>1</td>
<td>2, 4, 6</td>
</tr>
<tr>
<td>Alison, incorrect</td>
<td>F</td>
<td>20</td>
<td>1</td>
<td>2,4</td>
<td></td>
<td>3,5</td>
<td>6</td>
</tr>
<tr>
<td>Anne, incorrect</td>
<td>F</td>
<td>39</td>
<td>2</td>
<td>1,3</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Ellon, correct</td>
<td>F</td>
<td>48</td>
<td>2</td>
<td>3,5, 8, 10</td>
<td></td>
<td>1,4</td>
<td>7, 9, 11</td>
</tr>
<tr>
<td>Linda, correct</td>
<td>F</td>
<td>28</td>
<td>2</td>
<td>3,5, 7</td>
<td></td>
<td>1</td>
<td>4, 6</td>
</tr>
<tr>
<td>Monica, incorrect</td>
<td>F</td>
<td>42</td>
<td>2, 5</td>
<td></td>
<td></td>
<td>1,3</td>
<td>4</td>
</tr>
<tr>
<td>Grant, correct</td>
<td>M</td>
<td>30</td>
<td>2</td>
<td>3, 5, 7, 9, 11</td>
<td></td>
<td>1,4, 5</td>
<td>6, 8, 10, 12</td>
</tr>
</tbody>
</table>

**Comments.** This was a difficult question as a large amount of information had to be processed. It was important to compare alternatives and to carefully read the labels on the axes of the graphs. It can be seen that Grant's comments match the summary in the table.

Monica

The fastest stream was carrying the larger particles and that was the graphs that are higher ... the ones I'd be looking at ... I'm not sure ... so this one points to N (slowest) would be a slow one and this one is fastest (points to fastest) ... but is that right? It could be the other way ... then it doesn't make sense.

Researcher

Look at the bottom axis, the size of the particles increases from left to right. Which graph contains the biggest particles?

Monica

... that one and that one (points to correct answers) and these will be slowest

Researcher

The question says put them in order of increasing velocity going from the slowest to the fastest

Monica
Well those two are the fastest, that one would be the slowest, then that one, that one and that one (in the correct order).

Researcher

Did you look at the picture in the graph?

Monica

Yes without reading the labels.

Grant

I'm not overly confident here but I've gone for D. The thing that struck me here was the amount of information. The first thing I did was read the question, to try and get an understanding of it and I found that I kept going back to the question to make sure that I was understanding it properly. Then I looked at the graphs and I didn't look to much at the percentages because I assumed that it was like a quantity thing...I looked more at the particle size and from there I tried to work out could these be organised in relation to the opening statement. Like this is a fast flowing stream because it is collecting large particles. So once I had worked out the general pattern, I went down to here (points to alternatives) to understand this part of it...I wasn't sure what increasing velocity meant but I guessed it meant speed. Then I eliminated all the alternatives.

Table 5.15 summarises data from all observations and transcripts. Besides listing the number of times a specific form of information was referred to, it also indicates which forms of information were used at the start of a question.

TABLE 5.15: SUMMARY OF INFORMATION FROM THE OBSERVATIONS AND TRANSCRIPT ANALYSIS

<table>
<thead>
<tr>
<th>Form of information</th>
<th>Frequency of referrals</th>
<th>Frequency of first referral</th>
</tr>
</thead>
<tbody>
<tr>
<td>graph - global</td>
<td>63</td>
<td>10</td>
</tr>
<tr>
<td>graph - local</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td>table-local</td>
<td>33</td>
<td>2</td>
</tr>
<tr>
<td>read text (question)</td>
<td>64</td>
<td>37</td>
</tr>
<tr>
<td>compare alternative in text</td>
<td>110</td>
<td>0</td>
</tr>
</tbody>
</table>

Interpreting the table.

Refer to column 3 "Frequency of first referrals". Examination of this column shows that on 37 occasions (76% of the total) preservice teachers read the question before they examined the graphs and tables (row 5). On another 10 occasions (20% of the total) they looked at the graphs before they read the questions (row 2), while 2 (4%) looked at the tables (row 4).
The raw data should not be used to compare referrals among different forms of information, but can serve to identify the forms of information that are accessed when preservice teachers attempt to answer questions relating to the interpretation of graphs and tables.

**Summary of the data obtained from the interview transcripts**

The data are discussed under the broad headings of text and tables, and graphs.

**Text and tables**

The context always plays an important part in the interpretation of graphs and tables. Often terms such as "velocity", "viscosity" are not understood and this makes interpretation difficult. An excerpt from Ellon's transcript serves to illustrate this point.

She pointed to the text and remarked

> If you look at the question it asks you about the greatest number of elements discovered between certain dates. What does this mean? (points to the word 'element').

Thus it is important that key terms in the text are understood as often scientific terms have very specific meanings that may differ from common colloquial usage.

The transcript excerpts included with table 5.9 illustrate the problems associated with comparing data in tables. Often the reader has to re-sort values in his/her head and this creates cognitive load which inevitably leads to errors. As Alison said 'I had to try and keep the information in my head.' This problem was mentioned in 5 transcripts.

**Graphs**

When the preservice teachers were required to examine and interpret graphs they divided their attention between local and global features. At times they misinterpreted the graphs because they did not recognise that a relationship existed between a global feature (eg. a rise or fall or change in slope) and a specific local feature (eg. a specific value or label on an axis). Also they often failed to carefully read the details on axes (a local feature). However once the researcher directed the subjects' attention to the relevant local or global feature most could choose the correct answer. It appears that context-specific support was all that was needed. Other common errors included misreading labels and numbers on axes and the failure to comprehend legends.
As further discussion of these findings occurs in the discussion chapter, all that will be reported at this stage is that the data from the interview transcripts support the findings of Preece (1985) and Janvier (1978). They contend that learners not only have to accurately read the local and global information contained in graphs, but also that they need to relate the graph to its context. Furthermore the specific errors described are similar to those described in Preece and Janvier's studies.

The best science graduate (awarded the university medal in 1995) was also interviewed about how she answered the seven questions discussed with the Year 1 students. She correctly answered all questions and analysis of her methods showed that:

1. she read the question first every time;

2. when she referred to the graphs and table quickly she identified the key global and local features needed to answer the questions;

3. she then compared answers and referred back to specific local features on three occasions. On the other occasions she could select the correct answer without referring back.

This ex-student spent longer reading the question but did not have to refer back to the text, graph or tables. Also her comments showed that she had a very good understanding of the context of each question and this helped her to quickly identify which parts of the information were relevant. This suggests that she had the background knowledge and skills needed to quickly assimilate the information presented and to analyse it in order to solve a specific problem. Furthermore it appears that she was able to remember the information presented in the text, graphs and tables. By way of comparison, records of action for Alison (who scored 15/40) show that she referred back to information on many occasions (see figures 5.8 to 5.14). In one transcript Alison mentioned that she "had to try to keep the information in her head"; therefore it may be that her strategy of referring back to information was an attempt to deal with cognitive load.

The findings did not support hypothesis 1.1.1 as no differences were found between the performances of the Year 1 and Year 3 preservice teachers who were enrolled in the same degree. It appears that formal studies in education had no measurable effect on the ability of preservice teachers to interpret graphs and tables. However the findings did support
Hypothesis 1.1.2 and showed that the preservice teachers who have completed an undergraduate science degree prior to commencing the teacher education program were better at interpreting graphs and tables than those who have not completed such a degree. One explanation is that for the Year 4 students involved in this study, formal tertiary studies in science helped them to further develop skills in interpreting graphs and tables. Another explanation is that these students had already developed these skills before they entered tertiary studies.

Whilst some of the variation in the ability of the first year preservice teachers to interpret graphs was related to their Higher School Certificate scores in 2 Unit Mathematics, no other factors listed in hypothesis 1.1.3 were found to be significant. Follow up studies are warranted as they may help to identify which part(s) of the current 2 Unit Mathematics syllabus help learners to develop their skills in interpreting graphs and tables.

Two of the independent variables listed in hypothesis 1.1.4 were related: age and TER. The negative slope of the regression equation suggests that older preservice teachers tended to score lower TER's than younger preservice teachers. Because the amount of variation that can be attributed to this factor is small, it would be prudent to obtain a larger sample and to look at data from other universities before drawing any firm conclusions.

When the preservice teachers were interpreting graphs and tables, they had to process and interrelate many different forms of information. This was a complex and demanding task and created cognitive load as the learner grappled with unfamiliar text, graphs and tables. Another effect appeared to be that of split attention which may cause the learner to be distracted by information that was peripheral to the task at hand. These findings suggest that learners need support that helps them to identify and process information that is relevant to the task at hand. The cognitive tools developed for Study 2 were designed to provide such support and the chapters that follow discuss preservice teacher use of these tools.
Chapter 6: Study 2-Development and evaluation of the prototype

The findings from Study 1 were used to guide the development of the cognitive tools that supported the learner interpretation of graphs and tables. However, it was important that the graphs and tables were presented in a real life context that included supporting text as this is the way that we commonly encounter graphs and tables (Janvier, 1978; Preece, 1985). Rather than develop one specific tool and test it in isolation under so-called "controlled" conditions, it was decided to develop a suite of cognitive tools that could be used in a more holistic situation where text, graphs and tables were used together to present information about rainforest destruction.

The cognitive tools developed were designed to serve two broad purposes. First, tools were developed to assist learners to analyse information presented in text, graphs and tables, and second, a tool was developed to assist learners to synthesise information presented in text, graphs and tables. The tools designed to help learners analyse information presented in graphs also need to subtly focus learner attention toward relevant local and global features. However, the tool can be self-defeating if it is distracting and causes split attention. Therefore simple balloon help was considered as a means of attracting learner attention to relevant local and global features in graphs. Another tool developed to help reduce cognitive load was a simple sorting tool designed to help learners sort data presented in the table. The concept mapping tool was designed to help learners synthesise information. It was developed so that learners could create a simple concept map that represented their understanding of the information presented in the text, graphs and table.

Study 2 begins with a presentation of findings associated with the use of the prototype of the concept mapping tool, a tool that helps learners to construct (synthesise) knowledge. This is followed by a presentation of findings from the use of the "Rainforest" prototype (that was supported with all of the cognitive tools).
Methodology - Study 2

During Study 2 a concept mapping prototype was trialled with 63 preservice teachers enrolled in Year 3 of a Bachelor of Teaching (Primary) Degree. Interviews transcripts, journal entries and tracking data (which consisted of a software generated summary file of the frequency and time subjects spent in viewing each individual screen of the program) were gathered. The data were used to further refine the cognitive tools which would then be used in Study 3.

Table 6.1 displays summary statistics for the preservice teachers who participated in the trial of the prototype of the cognitive tools. All members of the group reported that they were experienced with computers.

Table 6.1: Composition of the sample that used the prototype (N=63; 57 females, 6 males)

<table>
<thead>
<tr>
<th>Preservice teacher experience with computers and high school education</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successful completion of an introductory subject in information technology</td>
<td>63/63</td>
</tr>
<tr>
<td>Uses a computer each week (at home, work or university)</td>
<td>63/63</td>
</tr>
<tr>
<td>Completed 6 years of high school English</td>
<td>62/63</td>
</tr>
<tr>
<td>Completed 6 years of high school Mathematics</td>
<td>47/63</td>
</tr>
<tr>
<td>Completed 6 years of high school Science</td>
<td>34/63</td>
</tr>
</tbody>
</table>

Age range 20 to 48 years, Mean 25.6, S.D. 6.8.

Research questions - Study 2

A brief discussion of the methods used to gather and analyse data associated with each research question follows. These methods are elaborated upon later in the chapter.

**Question 2.1**

Could the instructional strategies identified by researchers (Gunstone & White, 1992; Holley & Dansereau, 1984; Cambourne, 1988) in related fields be applied to introduce learners to the concept mapping tool?

Data from four sources were used: analysis of concept maps created by preservice teachers; interviews conducted with preservice teachers; observations made by experienced colleagues and field notes.
Question 2.2.

What effect does the concept mapping support tool have upon the way the learners structure their knowledge?

Two approaches were taken to this question. The first was an approach that analysed the maps and identified and discussed the changes. The second approach relied upon interview data gathered from a small sample (12) of preservice teachers after they used the prototype. It was anticipated that this question would be more fully answered when Study 3 was completed.

Question 2.3.

Did the cognitive support tools assist learners to analyse information in text, tables and graphs?

The following data were used to investigate this research question: journal entries; tracking data; interview transcripts; and brief observation notes written by the researcher during and immediately after a session. The latter were made as the opportunity arose and did not follow any structure. Instead they were brief descriptions of events considered to be important in the context of this study.

Question 2.4.

What evidence is there that these cognitive tools had an impact upon the concepts developed by the learners?

Once again multiple data sources were used to investigate this research question. First, the concept maps were analysed and the changes that occurred were discussed. Second, interview data were gathered from a small sample of preservice teachers (15) after they used the prototype of the "Rainforest" software. Other data were obtained from observations and field notes mentioned previously. The data from Study 2 were designed to investigate how the concept mapping tool helped learners to process information presented in the form of text, graphs and tables. The data also indicated which form(s) of information were used, and how the learners used the concept mapping tool to synthesise the information in a coherent cognitive structure. This research question was further investigated in Study 3.
Question 2.5.

Do the tracking files provide data which helps researchers to understand the way in which the tools were used?

In order to investigate this question, data from a computer generated tracking file of learner use of the software were analysed and then compared with data obtained from interviews, journal entries and general observations. This research question was further investigated in Study 3.

Variables selected during Study 2

The independent variables were attitude to computers as measured by Gressard and Loyd's instrument (1985) and the other independent variables from Study 1 (age, gender, marks from previous studies of English, Mathematics and Science, and experience with computers).

The dependent variables consisted of the total time taken to use the package and the frequency of referrals to the cards (this referred to as tracking data).

The tracking data provided an overview of how preservice teachers used the software. Follow up interviews were arranged with 12 pairs of subjects who were volunteers.

Attitude to computers

The instrument used was originally designed by Gressard and Loyd (1985). Gressard and Loyd (1985) originally administered the instrument to 192 teachers who attended professional development courses about computers. The age of these subjects ranged from 22 to 51 years which is similar to the age range of the subjects of this study at this institution (18 to over 40).

It is a Likert-type instrument that consists of thirty items which present positively and negatively worded statements of attitudes toward computers and the use of computers. The instrument was subjected to three validation studies which examined the reliability and factorial validity, correlation among the subscales and the results from a pre-program and post-program study. The same instrument was used by Massoud (1991) with a sample of 252 students and was validated with subjects who were adult college students. The alpha reliability coefficients for the three subscales of computer anxiety,
computer confidence and computer liking were respectively .72, .82, .70, and .90 for the total score.

In 1995 this instrument was trialled in a pilot study with the 63 subjects previously mentioned and the test-retest reliability data based upon correlation of total scores was .77, not as high as Massoud reported but still acceptable (Oppenheim, 1992, p. 129). As they completed the trial survey subjects were asked to write comments next to any questions they felt were ambiguous. Three questions were consistently identified as ambiguous. The same questions were also identified as ambiguous by two fellow researchers who read the questionnaire. It was decided to alter the wording of these three questions. The changes are shown in Appendix 4. The questionnaire was trialled again and this time subjects did not identify any ambiguous questions. A copy of this instrument is in Appendix 4.

**Kolb's learning style inventory (1971)**

A copy of this instrument is shown in Appendix 5. This appendix shows the questions and the method used for scoring. The more recent version (1984) was not used because of the cost involved. However the test-retest reliability of the instrument used was .74 which is within an acceptable range (Oppenheim, 1992, p. 159).

**The tracking data**

The tracking data consisted of a computer generated file that records details about how learners use the software. The data gathered from the tracking file provided information about which screens and buttons were chosen and time spent at each screen.

When a user logs on to the "Rainforest" prototype a file is created with the user's name and student number attached. As the user moves from card to card the program records which card is used and the total time spent with that card. The data is then stored as a file that is later converted to a comma-delimited file. This file is then imported into a statistical application package (StatView, Abacus Concepts, 1992) for further analysis.
**Analysis of concept maps**

The method of analysis of the concept maps was based upon consideration of the work of a series of researchers including: Beyerbach (1988); Harlen et al., (1990); Jonassen and Reeves (1996); Lloyd (1990); Novak and Gowin (1984); Shalveson (1993); and White and Gunstone (1992).

Novak (1984, pp.36-37) adopted a scoring procedure which consisted of:

- any relationships that are valid score 1 mark each;
- every valid level of hierarchy scores 5 marks each;
- cross links if valid score 10 marks each. If the cross link is valid but does not illustrate a synthesis between sets of related concepts and propositions it only scores 2 points;
- examples score 1 mark each.

However, Jonassen and Reeves (1996) suggested that researchers also need to consider the following when assessing semantic or concept maps:

- the number of nodes (breadth of the net);
- the number of instances (extent of the net);
- the ratio of instances to concepts (integratedness or embeddedness of the concepts);
- the centrality of each node;
- the number of links (parsimony or economy of connections);
- the consistency in the use of links;
- the number of "deadend" nodes linked only to one concept;
- the ratio of the number of links to the number of nodes.

Twenty concept maps created by preservice teachers were marked. The procedure was a modification of Novak's (1984) and included some of the criteria suggested by Jonassen and Reeves (1996). It is described below:
each valid concept label scores 1 mark. A concept has been defined in the context of this study as "anything that can be recognised, that is, that can be attributed identity" (Holley and Dansereau, 1984, p23). Thus ideas, objects, images, notions, conceptions, beliefs, events, features, properties, and states are examples of concepts;

- each note that defines a concept scores 2 marks. A note that defines a concept unambiguously describes its attributes;

- each valid single link scores 1 mark. A valid link is a line with an arrow attached that shows that two concepts are related;

- each note that clearly describes or explains the link to which it is attached scores 2 marks;

- each valid node - a concept that has valid links between two or more concepts - scores 2 marks.

For example the simple concept map below shows a concept map of the water cycle. The words on the links describe the nature of these links.

*Figure 6.1: A simple concept map used to show how the marking scheme was applied (after White and Gunstone, 1992)*

![Concept Map]

Notes are phrases and sentences attached to links and concepts. They demonstrate further understanding of the concept or link.
The map in figure 6.1 displays 8 concepts (scores 8 marks), no concepts had notes attached - zero marks were scored for this criterion, 10 valid links (scores 10 marks), each valid node (7) scores 2 marks (14 marks for the nodes), each labelled link (10) scores 2 marks (20 marks for the labels of the links). The total score is

\[ 8 + 10 + 14 + 20 = 52 \text{ marks}. \]

Twenty concept maps constructed during the first and last tutorial sessions were scored. Two experienced science teachers who held undergraduate science degrees independently applied the criteria described previously to score the same sample of twenty concept maps. Their scores agreed for 14 of the twenty maps. The difference between total scores for the other 6 maps was never more than 7 marks on any occasion. The procedure was considered to be only fairly reliable and was not adopted.

Shalveson (1993) and White and Gunstone (1992) report that some researchers use a criterion concept map for the material to be mapped. Then they divide student map scores by the criterion map score to give a percentage score which can be used for comparisons. It is important to realise that with this procedure it is possible that some students may score better than the criterion map and receive a percentage score that is more than 100%. Rye (1995) reported that a criterion map could be used with success when students studied the same topic (Global Atmospheric Change). In his study the expert maps were used to identify central concepts that could be used with a technique known as Pathfinder Network Analysis. This approach restricts the topic of the map to one domain of knowledge but for this study preservice teachers were not restricted in their choice of topics. Such an approach was not suitable in this context.

A statistical comparison test was considered, but rejected because there was a reliability problem with scoring. Similar problems have been reported by Shalveson (1993) and Kessler (1995). Furthermore even if statistical analysis indicates that an improvement in scores is probably not due to chance factors, it does not indicate how the improvements occurred and which aspects of the concept were better than the previous attempt.
After this trial and further study of the literature it was decided that reliance upon any such scoring system would be problematic. Extensive experience over a long period of time led White and Gunstone (1992) to state that "our personal preference is not to score concept maps" (p.39). Instead they argued for a more general approach that looks at the detail contained in the maps, the variety of relationships (particularly cross relationships) and links. More recent research by Shalveson (1993) reviewed the methods used to score concept maps and he concluded that "the variation in concept map assessments that we have described is enormous. Moreover these assessments are unlikely to produce equivalent scores" (Shalveson, 1993, p.18).

Because the total scores that can be obtained for a whole map are subject to variation, it was decided to analyse and describe the main attributes of the concept maps (concepts, links, notes, and hierarchal levels). This data could then be used to compare maps and to make descriptions of general and specific changes. The method for organising and analysing the data is similar to that reported by Beyerbach (1988) who used frequencies and descriptions to compared the main attributes of concept maps.

Journal entries were also gathered from 12 pairs of subjects who were also interviewed. The journal consisted of series of open-ended questions (described in Appendix 6) that asked subjects to work in pairs and reflect on the process.

**Analysis of the quantitative data gathered**

Regression analysis was used to test for significant relationships between the independent variable of attitude to computers and the tracking data. The data consisted of responses to the "attitude to computers questionnaire" (independent variable) and the tracking data (dependent variable) which contained user files that recorded the frequency and time that learners had spent using the various screens. Thus each tracking file recorded how many times a learner had visited each screen and how long they had spent there.

Two preservice teachers were used to trial the tracking system. Their individual sets of tracking data were gathered in ten-minute trial sessions and these were used to verify that the tracking process was working properly. This was done by comparing
their computer-generated tracking data log to an observer-generated log of software use. In both trials the data was the same.

The "attitude to computers questionnaire" (30 questions) consisted of three subscales (10 items each scale) that measure computer anxiety, computer confidence and computer liking. Subjects respond to each item on a four point Likert scale worded "strongly agree", "agree", "disagree" and "strongly disagree". The item responses were coded so that a higher score corresponds to a lower degree of anxiety and a higher degree of confidence and liking. The total scores for each subscale can range from 10 to 40, and the total for all three subscales can range from 30 to 120. Thus a high score on any subscale or on the total scale indicates a more positive attitude toward learning about or using computers.

**Data from journal entries and interviews**

Journals were filled in by 12 subjects who used the software. The following questions were asked:

1. Comment on the instruction provided during the first tutorial session.
   Specifically
   • Did the instruction help you to understand how to use the software?
   • What aspects of the process helped you?
     a. the demonstration by the instructor
     b. the practice session in the computer lab
     c. working with a partner
     d. all of these
     e. others - please specify below
   • Were there any aspects of the instruction that were confusing?

2. Describe any problems you experienced when using the software.

3. Please make any suggestions about how the software could be improved.
4. Are there any other comments that you want to make.

The following questions were asked of the subjects whose journal entries were analysed:

1. Describe what you did when you used the computer software to help you understand the information in the graphs and the table, and the text.

2. Describe what you did when you used the computer software to help you develop your concept map.

Development of the tools to support cognitive outcomes

It was important that the cognitive tools were presented in a real life context. Therefore, it was decided to develop a suite of cognitive tools that could be used in a holistic situation where text, graphs and tables were used together to present information about rainforest destruction. Several commercial applications were considered but none could be integrated into the context of this study (Appendix 11 contains a list of these software).

The concept mapping tool is discussed first as it was the first tool developed. When the application opens, explanatory text and instructions for logging on to the application are displayed on screen. A copy of this screen is shown in Figure 6.2 below.

*Figure 6.2: A plan of the opening screen of the prototype*
All user buttons were located along the right hand side of the screen and were accessible only after the user logged on. If the user tried to click on the buttons before logging on a pop-up message reminded him/her to log on first. This logging-on procedure created a user file that recorded their tracking data as well as the concept map created. The following descriptions explain the function of the five on-screen buttons.

**Buttons- function and description**

*Introduction*: The instructional text briefly explains how to get started.

*Concept map*. When the user clicked on the *concept map* button a pop-up palette called *concept tools* appeared at the bottom of the screen. This palette consisted of six buttons designed to help in the process of creating a concept map.

*Figure 6.3: The original six buttons on the concept tools palette*

The six buttons on this palette have the following functions:

- *concept* allows the user to type concept labels and to move these labels in two dimensional space;

- *link* allows the user to draw link arrows between concepts. Arrows indicate the direction of these links;

- *note* allows the user to attach explanatory notes to the links or concept labels. Therefore concepts and links can be explained;

- *eraser* allows the user to correct mistakes;

- *help* provides access to a simple help screen;

- *print* allows the user to print out the concept map and the notes.
The other on-screen buttons were

Help.  When a user clicks on this button, a pop-up window provides instructions that explain how to use the buttons appearing on the start-up screen.

Save.  This button allows the user to save the current map to the user's file.

Quit.  As the user quits the application, the concept map is also automatically saved, under the user's name, to a file server. The likelihood of accidental loss of information is reduced.

Figure 6.4 shows a screen capture of a student concept map about the solar system. After the preservice teacher logged on to the application, the concept mapping tools appeared and the section of the screen to the left of the buttons was blank. She then clicked on a button from the concept tools palette to begin constructing the map which appears in this figure. The view shows that she created a small number of key concepts and linked them. She was attaching notes when the screen capture was made. The attached notes are displayed for clarification but can be hidden by closing the window in which they appear. The double border surrounding the concepts (asteroids, moons) indicates that they have attached notes.
Development of cognitive tools used in the rainforest prototype

The cognitive tools described below were developed to assist learners analyse information presented in text, graphs and tables. Such tools included the balloon help and sorting tools. Originally the analytical cognitive tools were developed separately and briefly trialled before they were combined in the prototype. The prototype designed to support the interpretation of graphs and tables contained the concept mapping tool, but it also contained other cognitive tools as displayed on the screen shown in figure 6.5. The figure also displays the initial screen where the user logs on to the application.
Figure 6.5: The opening screen of the prototype of the support system to assist learners to interpret graphs and tables

Introduction

Helping you to interpret graphs

Introduction

This program is designed to help you to understand graphs. It consists of on-screen displays of graphs and tables plus on-screen buttons that you can click on to access tools or more information. The buttons always appear on the right-hand margin of the screen and are labelled. For example, if you click on the button labelled “Graph 1”, you see a view of the graph related to the topic that you are studying. If you click on the button labelled “Concept Map”, you access tools that help to create a concept map.

Instructions

Type in your name and student number in the space provided and press “return”.

Student Name ........................................
Student Number ........................................

The functions of the buttons displayed are described below:

The introduction explains the purpose of the support system; text provides a context for the information; questions are related to the information provided in the graphs and tables (in the final version the questions were also provided on paper) and the glossary provided further information about key terms. Figures 6.6 and 6.7 show the table support and the graphing support tools. The functions of the other buttons have been discussed previously.
The screen used to support the interpretation of tables allows the user to sort any data column (either in alphabetical order or numerical order) by clicking on the top of the column. In figure 6.6 the column labelled "Country" has been sorted alphabetically.
The screen used to support the interpretation of the graph allows the user to activate balloon assistance by moving the cursor over the text attached to the graph. In this figure the cursor is located over the data relating Papua and New Guinea, and the text in the balloon further explains the number at the end of the bar.

**Experimental procedure for Study 2**

All subjects were given a period of direct instruction in a lecture theatre that contained computer projection facilities. The concept mapping tool was presented and the
process of concept map construction modelled by the researcher. This was followed up with a one hour tutorial session in the multimedia computing laboratory. This laboratory consists of a room containing 14 Power Macintosh™ computers, plus one demonstration machine linked to a projector. All computers had hard disc drives, 1.4Mb floppy disc drives and were linked to a file server.

At the beginning of the first tutorial session the researcher used computer projection facilities to revise how to use the concept map creation tool demonstrated in the previous lecture. The preservice teachers were then given the choice of working alone or in pairs and all except three worked in pairs. Most felt that working in supportive pairs helped to facilitate the task of constructing their first concept map (which related to the topic of Astronomy). This topic was briefly presented in a previous lecture and as an aid to memory, they were provided with a very brief list of key concepts associated with the topic. Two copies of completed maps were printed at the end of the tutorial session: one copy was kept by the preservice teacher and the other collected for analysis. A debriefing session was held at the end of the tutorial session.

After analysis, the concept maps were returned during the following lecture and ways of improving the maps were discussed. Once again the computer projection facilities were used to model the process. The follow up tutorial was also held in the multimedia computing laboratory and during the session the preservice teachers revised and reprinted their maps.

After this session the maps were analysed and followed up as before. During the third tutorial session, the preservice teachers were asked to complete a final draft of their concept map. When the preservice teachers completed the construction of their final drafts of their concept maps the researcher interviewed twelve pairs of subjects about their experience with the process of concept map creation. Their responses were recorded on audio-tape and later transcribed for analysis. The follow up interview began by asking subjects to:

Describe what you were thinking about as you used the computer software to make your concept map.
The responses to this question were used as a starting point to raise all issues about this method of representing knowledge. At the conclusion subjects were given the opportunity to offer any other comments that they felt were relevant.

Twelve volunteers agreed to keep journals and these were analysed. The volunteers were informed that their responses would help the researcher to understand how they constructed their concept maps, how they used the concept mapping tool, and their general perceptions about the instruction they received. The following instructions were given:

1. Comment on the instruction provided during the first tutorial session.
2. Describe any problems you experienced in using the software.
3. Please make any suggestions about how the software could be improved.
4. Please add any other relevant comments.

The procedure for analysis of journals was as follows:

1. search for key words related to the questions and underline;
2. select a relevant quote and count the instances that similar comments were made;
3. use a colleague with a background in science education was used to re-check the journal entries and the quotes selected;
4. repeat the process when the colleague disagreed with the interpretations made.

Finally, all pairs of preservice teachers were allocated another four one hour computing laboratory sessions which they could use in their own time for the completion of concept maps. Thus each subject received was six hours of formal instruction, and another four hours of computer laboratory time was formally allocated to complete the maps.

As subjects used the software the researcher also made general observation comments that were recorded on a voice-activated micro cassette recorder. Later these comments
were summarised and used as a verification check on data gathered by other means, and to identify issues that needed follow up. Summaries of these general observations were verified by two researchers who were experienced in computer education. On two occasions they spent 60 minutes observing preservice teachers using the software and verified the findings.

**Use of all cognitive tools**

During this part of Study 2 the subjects were permitted to remain with the same partners as before (only three worked alone). The subjects who preferred to work alone were three males who had advanced computing skills (they had completed part or all of a computing science degree). This procedure was followed because it was felt that it created conditions of low anxiety that would allow subjects to concentrate on the task as well as provide useful feedback about the prototype as each partner would be able to confirm the views expressed by his/her partner. This meant that for Study 2 most of the concept maps were created by pairs of preservice teachers and only three individual maps were recorded.

However, the aim of research question 2.3 was to find out if the cognitive tools assisted learners to interpret information on the form of text, graphs and tables. Therefore, Study 2 was more concerned with the process than the product, and data from pairs of students were just as useful as those generated by individuals. Furthermore, the use of pairs enabled each partner to reflect on how the other used the software and thus this strategy provided useful data for interviews and journal entries.

**Results for Study 2: Learner use of the prototypes of the cognitive tools**

The concept mapping tool is discussed first as it was the first tool developed. The 63 subjects who used the concept mapping software were enrolled in Year 3 of a Bachelor of Teaching (Primary) degree in 1995. Table 6.2 displays the descriptive statistics for these subjects.
Table 6.2: Descriptive statistics for preservice teachers who used the prototype of the concept mapping tool

<table>
<thead>
<tr>
<th>Gender</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>57</td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
</tr>
<tr>
<td>Mean age = 25.6</td>
<td>SD = 6.8</td>
</tr>
</tbody>
</table>

Preservice teachers were allowed to work in pairs or alone. Most preferred to work in pairs and their preference supports research by Ramsden (1992) which showed that supportive pairs were beneficial to adult learning and lowered anxiety levels.

**General use of the tool**

It was observed that the construction of concept maps is a skill that initially requires careful instruction and this supports the claims of Novak and Gowin (1984) and White and Gunstone (1992). But, after the preservice teachers received instruction that modelled the process and completed a one-hour practice session in the computer laboratory, they needed little support with the process. This observation supports the research reported by Jonassen (1996). Indeed many subjects reported that they felt comfortable with the process after one tutorial session.

The researcher and two colleagues who taught in information technology subjects observed that the preservice teachers could easily navigate around the Macintosh™ user interface, and could use the software. Thus it appears that the software was easy to use and the cognitive load associated with navigation was low. The observations noted by the researcher showed that the mapping tool was easy to use and it seemed to become transparent to the user. This allowed the preservice teachers to focus on the cognitive processes involved in the construction of their concept maps.

Working in pairs was convenient because it made the exercise less threatening and also tended to encourage dialogue. Another benefit was time. Less laboratory time was needed as on average 22 persons attended each tutorial session. Thus only three one hour laboratory sessions were needed each week.
Use of specific features of the tool

The only concept map construction tool that needed further demonstration was the link tool as some preservice teachers needed to practise the "click and drag skills" required to draw links. To draw a link users must hold the mouse button down ("click") to start the link and then keep the mouse button down as they drag it across the screen to create a link line. Releasing the button ends the link. The buttons that were used as concept labels were of a fixed size. Most concept names created did not fill up all the available space, and this wasted a certain amount of screen space (Figure 6.4 is an example). This could become a problem when creating large concept maps so buttons that altered size according to the length of text were needed. Many preservice teachers wanted to revise their maps in their own time but they did not have access to the file server unless the researcher was present, so a "save to disc" and "load from disc" feature was needed. The preservice teachers also wanted to save their notes as a separate text file because they could use their own word processor applications to revise notes away from the computing laboratory.

Another problem observed was the screen space taken up by the palette of concept map construction tools. While the palette could be moved out of the way, many preservice teachers forgot that they could do this and as a result did not use the screen space efficiently. It was decided that the palette or tools should be modified to be a ribbon of tools that was fixed on the left hand margin of the screen.

Notes describing the functions of the tools were issued during the second week. While most preservice teachers did not require the notes, several made the comment that the notes may be helpful when they begin using the concept mapping tool. The researcher and colleagues who participated in observation checks felt that notes might be counter-productive as many preservice teachers learnt a great deal by self-exploration and gained in self confidence with computers.
Interviews with preservice teachers who used the concept mapping tool

The interviews provided data that could be used to triangulate the general observations as well as supplying new perspectives on the use of the tool. The researcher asked subjects to:

Describe what you were thinking about as you used the computer software to make your concept map.

The three subjects who worked alone were also interviewed (separately) but the 12 pairs were interviewed in pairs.

During these interviews, all three more advanced users claimed that they preferred to work alone because they could explore the program in depth and at their own pace. Analysis of field notes supports their claim as they took longer to complete the program. Thus they were not just focusing upon the task of constructing a concept map.

A comment from Robert (age, 24 who had completed two elective subjects in information technology) was representative of the others:

I wanted to find out about how the program worked and to critique it as I have an assignment that asks me to critique some software...I find that I can't play around with the program if I work with a partner.

Thus Robert appeared to have another agenda besides the one set for him. Gordon (age, 22) and Glenn (age, 26) were also experienced computer users and both indicated that they wanted to test the program out to see if it had any 'bugs' (Gordon’s comment). While they were involved in the task of creating the concept map, they also explored the organisation of the software.

Interview transcripts and journal entries from the 12 pairs revealed that they were more focused on the task and the comment from Kim (age, 22) and Sharon (age, 23) is an example:

...When we were creating the concept map, we kept thinking about the way the map looked and if the parts linked together.

Other interview transcripts showed that besides concentrating on the task at hand, preservice teachers were collaborating among their peers and the following quote is from Louise and Carla (in their early twenties).
The concept making tool was easy to learn. We probably didn't need to spend one tutorial practising as I was sure that I'd manage after the lecture...Louise and I didn't agree about where to put Gravity so we asked Nancy because she brought a book on Astronomy from the library. We used this book to help us check our concepts and spelling - sorry we are not good spellers! (L C)

Thus Louise (L) and Carla (C) collaborated with a peer in order to settle a dispute about 'gravity' and they asked Nancy who gave them a book to help them clarify their ideas. Louise and Carla also found the tool easy to use and felt that the tutorial session was not needed. This view is not supported by most preservice teachers as 27 pairs felt that the tutorial session gave them valuable experience in learning to construct a concept map.

Those who worked in pairs also claimed that working with a peer allowed them to 'bounce' ideas off each other and to refine their concept map, and the following quote is from two women in their thirties:

We wanted to make a good concept map because we will use it in our assignment...Jen thinks that we can use the same idea in Human Society and Its Environment... This computer program is good to work with and helps us to put our ideas together. (J F)

**Improvements that preservice teachers made to their concept maps**

Concept maps created during the second tutorial session were compared to those created during the first session. Thirty-three concept maps were analysed. Thirty were created by pairs and three were created by subjects working alone. Table 6.3 below displays the results of an analysis of these maps.

*Table 6.3: Analysis of the concept maps*

<table>
<thead>
<tr>
<th>Feature</th>
<th>Map 1 (33 maps)</th>
<th>Map 2 (33 maps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 linked concepts</td>
<td>33</td>
<td>2 linked concepts</td>
</tr>
<tr>
<td>3 linked concepts</td>
<td>31</td>
<td>3 linked concepts</td>
</tr>
<tr>
<td>4 linked concepts</td>
<td>12</td>
<td>4 linked concepts</td>
</tr>
<tr>
<td>&gt; 4 linked concepts</td>
<td>3</td>
<td>&gt; 4 linked concepts</td>
</tr>
<tr>
<td>Concept notes</td>
<td>mean no. of words 56</td>
<td>mean no. of words 164</td>
</tr>
<tr>
<td>Links</td>
<td>hierarchal links 17/33</td>
<td>hierarchal links 29/33</td>
</tr>
<tr>
<td>Link notes</td>
<td>clearly explains links in all instances 22/33</td>
<td>clearly explains links in all instances 28/33</td>
</tr>
</tbody>
</table>
In most cases, concept maps created in the second tutorial contained more concepts, and 10 out of 33 were organised in branches that contained more than 4 linked concepts. Only 3 of the first set of concept maps contained a branch with 4 or more linked concepts. Other improvements noted were greater use of link notes to clearly explain links, and more comprehensive descriptions in the concept notes.

The data relating to the concept maps may support the interpretation that the preservice teachers were becoming more experienced in the process of concept map construction. The concept mapping tool may have assisted them in this process, but this interpretation cannot be made without reference to other supporting evidence.

Journal entries of preservice teachers

The following comments are representative of the journal entries.

...I like the idea of having time to practise with the program before we made our concept maps. (Pam- 4 entries mentioned the practice sessions).

...The computer projector was excellent! I could follow the instructions on my computer as you went through it. (Julie- 8 entries mentioned the projector).

Add a printed sheet at the start to explain how to use the program. This would make the program independent of the instructor (Robert- 3 of the 12 entries mentioned this).

Make the link arrows moveable (Gordon- 2 of the 12 entries mentioned this).

The note tools are very helpful and are one of the strengths (Murial- 10 of the 12 entries mentioned this).

The journal entries support the data gathered from observations and interviews. None of the journal entries mentioned that the software was difficult to use and 7 entries mentioned that they could use the software at home if their concept maps could be saved to a floppy disc rather than to the network file server. At the time this was not feasible because the program used HyperCard version 2.2 which was only available at specified licensed sites at the university and most subjects did not have their own copy of this software.

During a group debriefing session held at the end of the final tutorial session, preservice teachers identified two important factors that they addressed in order to improve their concept maps. These factors were content knowledge and experience in constructing concept maps. Most preservice teachers reported that they used some time during the week between tutorial sessions to develop more subject content
knowledge and to refine the hard copies of their concept maps. When they came to
the second tutorial session most brought a revised concept map and support materials
such as books and summaries. This pattern continued for the next week and it
appears that many preservice teachers were motivated to make a concerted effort to
improve their knowledge of relevant subject matter.

The improvements in the concept maps could be expected and may be attributed to a
number of factors including practice, peer help, tutorials, lectures and the effect of the
concept mapping tool. Also the process of identifying 'gaps' in content knowledge
may motivate preservice teachers to increase their subject matter knowledge. Finally,
the preservice teachers suggested that the concept mapping tool could be used to plan
instruction. They claimed that the processes involved in the creation of concept maps
not only helped them to map their current knowledge about a topic but to also identify
areas that needed improvement. This part of the process would help them to plan an
instructional sequence because the visual display allowed them to view the scope and
sequence of their topic.

Use of cognitive tools that helped learners to analyse rainforest
data

The same 63 subjects who used the concept mapping tool also used these analytical
tools. They kept the same partners, so 30 worked in pairs and 3 worked alone. The
preservice teachers were instructed to examine all features of the software and to
construct a concept map that summarised what they had learnt. The data is organised
under the headings of tracking data, interviews and journal entries.

Analysis of the tracking data that recorded preservice
teacher use of the software

The tracking data was gathered with tracking software that operated in the
background. After a user logged on to the HyperCard™ application, the tracking
software kept a log of the number of times buttons (which linked to a particular form
of information) were accessed and the total time the user spent looking at each form of
information.
Table 6.4 displays the summary statistics for the tracking data gathered from 63 subjects who use the prototype of the cognitive tools. The data shows that the mean time was 38.9 minutes and the total time varied from a minimum of 18.8 minutes to a maximum of 84.4 minutes. Those who took longer than 60 minutes discussed aspects of the software as they used it. Therefore they could have completed the task in a shorter time, but their comments were valuable data so the researcher did not remind them to stay on task. Instead he noted their names so that their tracking files could be identified.

**Table 6.4: The summary statistics from the tracking data from the prototype**

<table>
<thead>
<tr>
<th>Mean Time</th>
<th>38.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Deviation</td>
<td>21.</td>
</tr>
<tr>
<td>Minimum</td>
<td>18.8</td>
</tr>
<tr>
<td>Maximum</td>
<td>83.8</td>
</tr>
</tbody>
</table>

Table 6.5 displays the data from all tracking files. It shows number of times that subjects viewed a specific screen and in the column labelled 'time' the total time in seconds spent viewing the screen is displayed. Columns also display the total time subjects spent in using the software during this trial session, and the total number of referrals to the on-screen cards made by each subject.

The column headings refer to specific screens. The label 'Text' refers to the text screens; 'Quests' refers to the screen that displays the questions about the rainforest data; 'Table' refers to the table displayed on screen; 'Graph 1' refers to the first graph displayed; 'Graph 2' refers to the second graph displayed; and 'Cone, map' refers to the screen that contains the concept mapping tool. Examples of these screens have been shown earlier in this chapter.
Table 6.5: Summary of tracking data

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<tr>
<th>Initials</th>
<th>Text freq</th>
<th>Time mins</th>
<th>Quests freq</th>
<th>Time mins</th>
<th>Table freq</th>
<th>Time mins</th>
<th>Graph 1 freq</th>
<th>Time mins</th>
<th>Graph 2 freq</th>
<th>Time mins</th>
<th>Conc. Map</th>
<th>Time mins</th>
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</table>
The frequency distribution of the total time to complete the activity is shown in table 6.6.

**Table 6.6: Frequency distribution of the total time taken to use the prototype (N=33 groups)**

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<th>From: (s)</th>
<th>To: (&lt;)</th>
<th>Count</th>
<th>Percent</th>
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<td>81</td>
<td>88</td>
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</table>

This was the first time that they had used the software that contained the graphs and the tables. The 5 preservice teachers who spent more than 61 minutes using the software experimented with the software and spent additional time discussing possible improvements with the researcher.

**Journal entries from preservice teachers**

Text from the 12 journal entries were underlined and coded under the categories of text, table and graphs, questions and general comments.

**Tools that assist in the analysis of information**

The journals mentioned that the text was easy to understand and interesting (7 entries) but the size of the font (12 point palatino) should be increased to 14 point palatino (4 entries from mature age preservice teachers - age >35). "We older students with failing eyesight, need bigger print" (MG).

Other journal entries mentioned that the glossary was a useful feature but felt that actual words should be directly linked to the glossary rather than via an on screen button labelled "glossary". The glossary contained pictures that illustrated the terms and the opinions expressed in the journal entries were divided about this feature.
Three specifically mentioned that it was a useful feature but another four mentioned that the pictures did not add any meaning to the words.

The table sorting tool was considered to be a good support tool but again the size of the font was criticised (4 entries). Also the balloon help that provided text description of specific numbers on the graphs was considered a good support feature (8 entries) but the following criticism was made:

I wanted to know where the countries were located but you didn't provide a map.
This was frustrating (MK).

**The questions provided**

The quote from AB's journal follows and shows how she and her partner answered the questions:

B. and I read the text and then looked at the questions. Then we started to read the text again but we decided that we didn't have to do this, because it looked like the graphs and table would tell us about the rainforest losses...When we did our concept map we decided to do it out of our heads rather than look back at the screens. I know this was lazy on our part... (AB).

The questions focused upon finding and comparing factual information and could be answered by referring to the graphs and/or the table. Thus these preservice teachers did not need to use the text as a source of information.

Three journal entries mentioned that they found the questions difficult to use because they were on a separate screen. Once again the size of the font was criticised and the following quote illustrates this point of view:

...If we have to go backward and forward, we get impatient... (AB).

To overcome this problem it was decided that the questions would be presented on paper as well as on screen in the final version.

**General comments made by preservice teachers**

The journal entries showed that most subjects (8/12) referred back to the text, when constructing their concept map, but only one mentioned referring back to the graphs.

The following quote from JS's journal (time taken = 26.2 minutes) indicates how one pair of students used the software. They focused on the construction of their concept map and did not answer all of the questions.
We didn't have any really serious problems, except when we tried to save our map on to a floppy disc. We had forgotten that it was saved on the network disc and we were worried that our work was lost...We asked M. and she showed us where our map was saved...

We were happy with the look of the printed map we made. We were sure that we had used the program properly, but we didn't answer all the questions.

However, another pair of subjects took their time to review the information presented and they claimed that this helped them to gain a better understanding of the information presented and to construct a good concept map. They (L,E) used the software for 52 minutes and stated:

...E and I wanted to produce a really good concept map so we took our time and went back to the screens as many times as we wanted. This way we were able to find some more information to put in our concept map...

**Interview transcripts**

Subjects whose journal entries were analysed were asked to:

1. Describe what you did when you used the computer software to help you understand the information in the graphs and the table, and the text.
2. Describe what you did when you used the computer software to help you develop your concept map.

Seven pairs of subjects mentioned that they found the balloon help on the graph to be useful. Six pairs mentioned that the sorting tool for the table was a "good idea" (LE) and thought that it made it easier to understand the table.

The interview data showed that there were few problems associated with learner use of the software and hardware. However a number of design improvements were suggested by the subjects. These suggestions included: the location of the questions; the addition of a map to show the location of the countries described in the text; the rearrangement of buttons to take up less screen space; the inclusion of a button that switched the balloon help on and off; and the provision of a one page summary of simple user instructions rather than three pages of instructions.

**Summary of Study 2: Use of the prototypes of the cognitive tools**

The data indicated that the preservice teachers did not have difficulty in using the software. The cognitive tools designed for analysis of information (linked to the text, graphs and table) required minimal instruction and most preservice teachers
understood how to use them after one demonstration. All that was needed after this instruction was a summary sheet of instruction to serve as a reminder.

The concept mapping tool was a more complex tool to learn as it also involved learning a procedure, but a one hour demonstration followed by a one hour tutorial/practice session was all that was needed for preservice teachers to become independent users of the tool. Indeed many did not need the additional hour of practice.

While it may have been easy to learn to use the concept mapping tool, the cognitive processes involved in synthesising information are more complex and require practice. Thus use of the concept mapping tool may soon become obvious, but the process of synthesising knowledge into a powerful integrated structure takes time to learn and requires the learner to spend time away from the computer to find more information and to construct meaning.

The use of computer projection facilities to demonstrate the use of the tool to model the concept mapping process proved to be a powerful way to introduce the tool to a mass audience. In particular the preservice teachers liked the process of joint construction. During this process the researcher and the audience jointly constructed a concept map. The researcher "thought out loud" (articulated his thoughts) as he created a specific concept map suggested by the preservice teachers. Throughout the process the preservice teacher audience were encouraged to assist and to make suggestions that improved the concept map. The benefit of this approach was that it made explicit the cognitive processes used by the demonstrator.

The data also identified specific improvements that could be made to the tools and in the procedure. The improvements accomplished were to:

- increase the size of the font of the text to 14 point;
- directly link key words in the text to the glossary. It was decided that "hot" words would be identified by red letters and the user could click on "hot" words in the text to link to further information in the glossary;
- increase the size of the font of the text in the table;
locate questions adjacent to relevant text, table or graphs, or provide a separate question sheet. However, the location of questions next to specific information sources created three problems. First it forced questions to be worded so that they related to the specific form of information. Second the question took up valuable screen space. While answers could be typed in and saved, too much screen space was occupied. Therefore a separate sheet of paper was provided as well as on screen questions already provided;

- reword questions so that the user is forced to access different forms of information presented. Users could access a variety of information sources in order to answer some of the question. This feature is designed to encourage deeper processing of the information presented;

- use of balloon help to display a map which shows the location of the countries listed along the axes of the graphs;

- re-arrange buttons to take up less screen space - this feature is designed to create screen space and to make navigation a little easier;

- include a button that switched the balloon help on and off. This feature allows learners to decide if they want to use the balloon help;

- revise the concept buttons so that the size altered to suit the length of text in the concept name. This feature saved screen space;

- revise the shape of the concept tools palette so that it is a ribbon located along the left hand margin of the screen. This feature saved screen space and was simpler to manage than a moveable palette. Figure 6.8 shows the redesigned tools palette.
provide 'save to disc' and 'load from disc' functions for the concept mapping tool. This feature will allow users to develop their maps outside of formal tutorial times;

- save the concept notes and link notes as a simple text file so that users can take these home and revise them with their own word processor application;

- make the arrow links in the concept map moveable. This feature was trialled but not used as the re-arranged map still needed alteration because the moved links and concepts often overlapped with other links and concepts. Therefore some still had to be deleted and redrawn. This was particularly so with large and complex maps;

- provide a one page summary of simple user instructions. This feature provides a one page overview of the software.
Study 2 investigated preservice teacher use of the cognitive tools developed. The data suggests that the instructional strategies employed were effective and that the software was easy to use.

As the preservice teachers became more familiar with the concept mapping tool and with the procedure of concept mapping, their maps became more organised and more complex. They created more links among concepts and made more extensive notes that explained their concepts and the links they created. This may be an indication that the preservice teachers were beginning to use the concept mapping tool to restructure their knowledge into more powerful, integrated frameworks.

The preservice teachers found that it was easy to use the cognitive tools designed to assist them analyse the information about rainforest destruction. In most cases only minimal instruction (a single demonstration) was required. The data from interviews and journal entries suggests that the glossary, table sorting tool and the balloon help features were used, and these tools helped the preservice teachers to gain a better understanding of the context of the information presented.

While some of the preservice teachers went back to graphs and tables when constructing their concept map about rainforest destruction, the majority referred to the text and the glossary. However, the sample interviewed was small and further investigation of this aspect is needed. At this stage of the study it appears that the text and the glossary were the main sources of information used when preservice teachers constructed their concept maps.

The tracking data provided information about the time and frequency of use of the cognitive tools. The data showed that it would be dangerous to rely solely on this information as misleading results can occur when learners are off-task. Therefore, it is important that an observer be present when the software is used because any irregularities in the use of the software can be noted.

Study 1 had identified cognitive strategies that learners use when they interpret graphs and tables, and consequently the prototype analysis tools were designed to support these cognitive strategies. Both Studies 1 and 2 were used to guide further improvements in the design of the cognitive tools. The cognitive tools assisted some
learners to interpret text, graphs and tables. Study 3 addresses this issue in more detail and also reports on preservice teacher use of the concept mapping tool is studied in more extensively.
Chapter 7: Study 3-Use of the concept mapping and information handling cognitive tools

Study 3 was designed to investigate preservice teacher use of the redesigned cognitive tools and concept mapping program. Studies 1 and 2 results were used to guide the improvements that were made to the cognitive tools and these new features are briefly described in table 7.1.

Table 7.1: New features of the improved version of the rainforest program

<table>
<thead>
<tr>
<th>Feature</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>On/off button for balloon help</td>
<td>turns balloon help on and off</td>
</tr>
<tr>
<td>Map link</td>
<td>shows the location on a world map of the countries listed in the graphs and tables</td>
</tr>
<tr>
<td>Revised palette of concept mapping tools</td>
<td>the tools buttons are arranged in a left to right order that mirrors the way most subjects used the tools in the trial version of the prototype</td>
</tr>
<tr>
<td>Expanding box around concept label</td>
<td>places no restriction on the size of the concept names, more efficient use of screen space</td>
</tr>
<tr>
<td>Horizontal arrangement of the buttons</td>
<td>this creates more screen space for the concept map</td>
</tr>
<tr>
<td>Save to disc function</td>
<td>allows subjects to save their concept map to a floppy disc, so that they can keep a copy of their work.</td>
</tr>
</tbody>
</table>

The improved version of the application is illustrated in the following captured screens.
Figure 7.1: The revised opening screen

Figure 7.1 displays the revised opening screen and the relocation of the on screen buttons. The revised concept mapping tool is shown in figure 7.2. The palette in the upper right hand corner was eventually altered to a vertical ribbon that was permanently located along the left-hand border of the screen.

Figure 7.2: The revised concept mapping tool
The revised tools for interpreting tables are shown in figure 7.3. It shows how the size of the font was increased and the amount of data increased. The second left-hand column has been sorted and countries re-named according to the 1994 edition of the Times Atlas of the World (Time Books, 1994).

Figure 7.3: The revised display of tabular information

<table>
<thead>
<tr>
<th>Original area of rainforest 1000 km²</th>
<th>Present area of rainforest 1000 km²</th>
<th>Annual rate of loss</th>
<th>% left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>500</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>Nigeria</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Kenya</td>
<td>500</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>Sudan</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Peru</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>New Caledonia</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Italy</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>South America</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>India</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>China</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Australia</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>New Zealand</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

The table shows some countries that contain rainforests. The countries chosen are representative examples. Numbers in the columns labelled 'Annual rate of loss', '% left' are percentages. The column labelled 'years to end' tells you how many years are left before the rainforests will be completely destroyed. This column assumes that the current rate of deforestation will continue. Click on the first text to sort columns.
The revised tools for interpreting graphs are shown in figure 7.4. It shows how the balloon help feature displays the location of a country when the cursor is located over the name of the country. In this figure the location of Zaire is displayed.

Figure 7.4 : The revised balloon help for the graphs

Research questions and hypotheses - Study 3

The methods used to gather and analyse data associated with research questions 3.1, 3.2 and 3.3 have already been described in Chapter 6. These questions were:

**Question 3.1.**

Could the instructional strategies identified by researchers (Gunstone & White, 1992; Holley & Dansereau, 1984; Cambourne, 1988) in related fields be applied to effectively introduce learners to the concept mapping tool?

**Question 3.2.**

What effect does the concept mapping support tool have upon the way the learners structure their knowledge?
**Question 3.3.**

Did the cognitive support tools assist learners to analyse information in text, tables and graphs?

Research questions 3.4, 3.5 and 3.6 focused upon learner use of the cognitive tools and the results are presented later in this chapter.

**Question 3.4.**

What impact did these cognitive tools have upon the concepts developed by the learners?

To investigate this question it was necessary to draw upon techniques that allow the researcher to find out what concepts have been developed and which forms of information were accessed. Therefore data from concept map analysis, interviews, and preservice teacher tracking files were used. The concept maps were analysed first to identify any differences in the way the maps were constructed. Any patterns that emerged were compared and then the data were compared with data from other data sources such as the tracking files and the interviews. A certain amount of re-analysis of the data was anticipated as emerging trends would force re-examination of specific aspects of the data.

**Question 3.5.**

Do tracking data provide insights about the way in which the tools were used?

The tracking data were collected automatically after the user logged on to the software. The data were displayed as a spreadsheet table which indicated the total time and the frequency that a user viewed each screen. These data were compared with data from other sources in order to substantiate whether the primary data alone can provide reliable information to instructors.
Question 3.6.

How did the learner access information within the application?

Again multiple data sources were used. Tracking data were used to describe the frequency and time that the learner spent processing the various information sources: the tracking data recorded; the total time spent at each information screen; and the number of times each screen was accessed. This data was compared with interview transcripts and with data from the analysis of concept maps.

Hypothesis 3.6.1

The independent variables of positive attitudes to computers, male gender, a younger age, and preferred learning style will predict greater time spent in using specific information screens.

Hypothesis 3.6.2

The independent variables of positive attitudes to computers, male gender, a younger age, and preferred learning style will predict higher frequency of subject referrals to specific screens of information.

Experimental procedure - Study 3

During this study Year 3 preservice teachers (n=80) used the rainforest application. They used the concept mapping tool before they used the information relating to rainforest destruction. Because individual concept maps were required preservice teachers had to work alone when they used the improved version of the software.

The improved version of the application was used over a five week period. During this time preservice teachers received four formal lecture/demonstrations and five one-hour tutorials. As each tutorial group consisted of 12 to 14 preservice teachers, 6 hours of laboratory time were required each week for the 80 subjects. The computing laboratory was also available for further use for 6 hours each week. Table 7.2 describes how the formal instruction time was organised and when the concept maps were collected.
Table 7.2: Organisation of instruction and collection of data

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture</th>
<th>Tutorial</th>
<th>Data collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to the tool and joint construction of a concept map about astronomy</td>
<td>practice</td>
<td>journal entry, practice maps</td>
</tr>
<tr>
<td>2</td>
<td>Feedback on practice maps</td>
<td>further practice</td>
<td>journal entries</td>
</tr>
<tr>
<td>3</td>
<td>Description of planning task- joint construction of an example</td>
<td>construction of map 1</td>
<td>map 1, journal entries</td>
</tr>
<tr>
<td>4</td>
<td>Feedback on map 1</td>
<td>map 1 revision,</td>
<td>journal entries</td>
</tr>
<tr>
<td>5</td>
<td>No lecture about concept mapping</td>
<td>complete map 2</td>
<td>map 2, journal entries</td>
</tr>
</tbody>
</table>

Preservice teachers were instructed in the use of the concept mapping tool. This ensured that each subject who used the improved version of the rainforest application was familiar with the user interface and had six hours of formal instruction in concept mapping procedures. During the final tutorial session subjects were asked to use any of the cognitive tools available to help them to process the information in the text, graphs and tables presented. All subjects were instructed to use the concept map tool to create a map of their understanding of the information presented on the screens. While they were completing this task, the tracking software monitored subject use of the software, and the researcher made notes of any events that needed to be followed up with interviews. At the end of the session all completed concept maps were saved to each subject’s disk file and later printed out by the researcher. Any subjects who needed more time to complete their concept map had the opportunity to continue as there were four spare computers available in an adjacent multimedia production room. If this was inconvenient subjects could also come back at another time as the tracking program could accumulate data from multiple files of single users.

Results from Study 3: Researching use of the improved cognitive tools

Use of the improved concept mapping tool

The concept mapping tool was used to construct concept maps about a science topic chosen by preservice teachers. The map had to include concepts that were suitable for the primary school class that the preservice teachers would instruct later in the year. Also instructional activities had to occupy approximately 15 hours of instruction time. Thus the
choice of topic was restricted to those listed in the current Science and Technology syllabus for primary schools in NSW (Department of School Education, 1991) and the program of the school where they were to teach. Table 7.3 displays the list of topics chosen by the preservice teachers for their first and second maps. The right-hand column shows that there was little change in the topics chosen.

Table 7.3: Frequency distribution of the topics chosen by the preservice teachers

<table>
<thead>
<tr>
<th>Topic for map 1</th>
<th>Freq 1 F1</th>
<th>Topic for map 2</th>
<th>Freq 2 F2</th>
<th>Change F2-F1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptations</td>
<td>3</td>
<td>Adaptations</td>
<td>2</td>
<td>-1</td>
</tr>
<tr>
<td>Animal Classification</td>
<td>1</td>
<td>Animals in school</td>
<td>1</td>
<td>*</td>
</tr>
<tr>
<td>Astronomy &amp; Space</td>
<td>10</td>
<td>Astronomy &amp; space</td>
<td>9</td>
<td>-1</td>
</tr>
<tr>
<td>Australian Plants/Animals</td>
<td>2</td>
<td>Air</td>
<td>1</td>
<td>*</td>
</tr>
<tr>
<td>Chemical reactions</td>
<td>1</td>
<td>Chemical reactions</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Communication</td>
<td>5</td>
<td>Communication</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Electricity</td>
<td>2</td>
<td>Electricity</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Energy</td>
<td>2</td>
<td>Energy</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Environmental studies</td>
<td>9</td>
<td>Environmental studies</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Flight</td>
<td>4</td>
<td>Flight</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Food production</td>
<td>1</td>
<td>Food production</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Forces</td>
<td>1</td>
<td>Forces</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Geology</td>
<td>3</td>
<td>Geology</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Human Body</td>
<td>9</td>
<td>Human Body</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Light</td>
<td>5</td>
<td>Light/colour</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Magnetism</td>
<td>2</td>
<td>Magnetism</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Plants</td>
<td>3</td>
<td>Plants</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Sound</td>
<td>5</td>
<td>Sound</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>Technology</td>
<td>6</td>
<td>Technology</td>
<td>4</td>
<td>-2</td>
</tr>
<tr>
<td>The Senses</td>
<td>1</td>
<td>The Senses</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Time</td>
<td>2</td>
<td>Time</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1</td>
<td>Viscosity</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Weather</td>
<td>2</td>
<td>Weather</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>80</td>
<td>Total</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>
Changes in topics

Six preservice teachers changed topics within those already listed above and two preservice teachers changed to a topic that was not in the original list. The eight changes in topics were caused by factors outside the control of the researcher and the preservice teachers; these were changes in teaching staff at schools and alterations to the teaching schedules at schools.

The topics and frequencies were re-grouped under syllabus headings of: Biology; Chemistry; Physical phenomena (including the weather); Astronomy; Geology; and Technology (including food technology and communication). The frequencies are displayed in table 7.4

Table 7.4: Frequencies of the most popular topic areas in the first and second concept maps

<table>
<thead>
<tr>
<th>Topic area</th>
<th>Frequency Map 1</th>
<th>Frequency Map 2</th>
<th>Freq 2- Freq 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>28</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Physical phenomena</td>
<td>26</td>
<td>29</td>
<td>+3</td>
</tr>
<tr>
<td>Astronomy</td>
<td>10</td>
<td>9</td>
<td>-1</td>
</tr>
<tr>
<td>Geology</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Technology &amp; Communication</td>
<td>12</td>
<td>10</td>
<td>-2</td>
</tr>
</tbody>
</table>

Again this table illustrates the stability of topic choices and shows that 95% of the topics chosen related to the following: Biology (35% of topics); Physical Phenomena (32.5%); Astronomy (12.5%) and Technology (15%). These topic areas form the major part of the current Science and Technology Curriculum for primary schools in New South Wales (Board of Studies, 1991) and reflect the criteria the preservice teachers applied to the topic selection.

Analysis of the concept maps created with the tool

The first part of the analysis compares the concepts and the notes contained in the maps. This data consisted of frequencies of concepts created by the preservice teachers. Therefore a paired t-test was used to compare the number of concepts found on the first map with those found on the second map. The same argument applies to the other t-tests
employed to analyse similar data in this section of the chapter (Howell, 1992, pp. 189-190).

Eight data sets were eliminated from the analysis because it would have been invalid to compare the first and second maps of the 8 preservice teachers who changed their topic (in these cases the second maps contained a similar numbers of concepts to the first).

While there was a slight increase in the number of concepts listed on the maps, the results of a paired t-test show that the difference is not statistically significant at the .05 level of significance ($t=-1.7$, $df=71$, $p=.095$). However, the addition of more concepts on a map is not necessarily an indicator of a better concept map as it is more important that concepts are organised and linked into powerful integrated frameworks (Jegede, Alaiyemola, & Okebukola, 1990).

It may be more important to examine the notes created by the preservice teachers as the number of concept notes and the link notes were far greater in map 2 than in map 1. Table 7.5 summarises the descriptive statistics associated with this data.

**Table 7.5: Summary statistics for the concept notes and link notes associated with concept maps 1 and 2**

<table>
<thead>
<tr>
<th>Key</th>
<th>Cnotes1=concept notes &amp; link notes in map 1, Cnotes2=concept notes &amp; link notes in map 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X1 : Cnotes1</td>
</tr>
<tr>
<td>Mean:</td>
<td>Std. Dev.:</td>
</tr>
<tr>
<td>2.7</td>
<td>2.6</td>
</tr>
<tr>
<td>Minimum:</td>
<td>Maximum:</td>
</tr>
<tr>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

| X2 : CNotes2 |
| Mean: | Std. Dev.: | Std. Error: | Variance: | Coef. Var.: | Count: |
| 12.4 | 5.7        | .7          | 32.7      | 46.1      | 72     |
| Minimum: | Maximum: | Range: | Sum: | Sum of Sqr.: | # Missing: |
| 3    | 33         | 30         | 893       | 13397     | 0      |

| X3 : Lnotes1 |
| Mean: | Std. Dev.: | Std. Error: | Variance: | Coef. Var.: | Count: |
| .7   | 1.3        | .2          | 1.8       | 194.3     | 72     |
| Minimum: | Maximum: | Range: | Sum: | Sum of Sqr.: | # Missing: |
| 0    | 6          | 6          | 50        | 164       | 0      |

| X4 : Lnotes2 |
| Mean: | Std. Dev.: | Std. Error: | Variance: | Coef. Var.: | Count: |
| 5.7  | 5.5        | .6          | 29.8      | 95.9      | 72     |
| Minimum: | Maximum: | Range: | Sum: | Sum of Sqr.: | # Missing: |
| 0    | 22         | 22         | 410       | 4452      | 0      |
A paired t-test showed that there was a statistically significant difference \((t=12.4, \text{df}=71, p=.0001)\) between the number of concept notes attached to each map. Similarly, a paired t-test showed that a statistically significant difference \((t=7.4, \text{df}=71, p=.0001)\) in the number of link notes attached to each map. This may be a better measure of the quality of the maps.

The number of cross links was also compared and again there was a statistically significant increase in the number of cross-links in the second map \((t=2.2, \text{df}=71, p=.0292)\). The levels of hierarchy were also compared and again there were significant increases in the number of levels of hierarchy \((t=4.9, \text{df}=71, p=.0001)\).

The statistical tests on data that compared the first and second maps showed the improvements observed were unlikely to have occurred by chance. The improvements were: an increase in the number of concept notes and link notes; an increase in the number of cross-links; and an increase in the number of levels of hierarchy. These increases indicate that the preservice teachers improved in their ability to construct concept maps. Several factors would have contributed to this improvement and these include further practice with the tool, additional instruction in concept map construction, help from peers as well as research away from the computer.

In the past, researchers such as Novak and Gowin (1984) have compared total scores allocated to each map, but the concept mapping tool used in this study allows users to include attached notes and this adds another dimension. Therefore it may be more useful to consider each feature separately rather than in combination. The notes, in particular need further analysis and during this study two approaches were used. One was to simply count total words written in the notes created for the first concept map and compare it to the total for second concept map. The second approach was to examine the content of the notes.

A paired t-test was used to compare the total words written in the notes attached to concepts in concept map 1 to those in concept map 2. The results were again significant \((t=11.4, \text{df}=71, p=.0001)\). A similar result was obtained when the total words written in the link notes in concept map 1 were compared with those in concept map 2 \((t=6.3, \text{df}=71, p=.0001)\). While the results of this analysis show that the increase in the number
of words contained in notes was statistically significant, this analysis does not measure any improvement in the content of these notes.

When the contents of the notes were examined, the following improvements were noted. The concept notes attached to map 2 contained accurate definitions (95% of maps for map 2; 83% for map 1), and outlines of instructional activities that could be used to explain the concepts to children (89% of maps for map 2; 57% for map 1). The link notes provided information about one or both of the two concepts linked (32% of maps for map 2; 13% for map 1), or explained the link (58% of maps for map 2; 12% for map 2). Link notes were not as lucid as the concept notes and this finding supports the claims of White and Gunstone (1992) that students find it difficult to write links and it takes longer to acquire the skill of writing good link notes.

**Interview data about the use of the concept mapping tool**

Two interviews were conducted with fourteen preservice teachers. Their ages ranged from 22 to 48 years and represented a cross-section of the ages in the cohort. The first took place within a week of completing the first concept map and the second occurred within a week of completing the second concept map.

Before the interviews the preservice teachers were advised that they should bring their printed concept maps and any reminder notes to the interviews as they would be discussing the concept maps they created and how they used the concept mapping tool. A copy of the interview questions appears in Appendix 7.

The interview transcripts were coded and common themes collated. Then instances in the transcripts were identified and illustrative quotes collated. The common themes that emerged from this process are discussed under the headings of: initial concerns, use of the tool to construct concept maps, revision of concept maps, and other uses of the concept mapping tool.

**Initial concerns**

When the students began creating their concept map they had concerns about what a concept map is, how to construct a concept map and about the technology they were to
employ. These concerns are discussed under these headings and relevant quotes from the interview transcripts are used to illustrate these issues of concern.

**What is a concept map?**

The quote from Ruth (aged, 30) is typical of the students (2 of the 14 interviewed) who had past experience with the less formal procedure of "mind mapping" (Buzan, 1995). She stated "I'm not really sure, everyone seems to have a different view of what a concept map is about." While Ruth claimed that "everyone seems to have a different view", further discussion revealed that she was comfortable with the process of mind mapping, but found the rules of the concept mapping process more restrictive. However those students (12 of the 14 interviewed) who were not familiar with other semantic mapping procedures readily accepted the concept mapping procedure presented and were more certain about what they had to do. This is an example of where prior learning experiences may initially interfere with new learning experiences.

**How to construct a concept map**

Again Ruth (aged, 30) who had prior experience took a different approach to the construction of her concept maps. She stated that "I tended to bury a lot of the information in the notes and I felt... all of the concepts are buried in the notes". While her method of construction was different to those used by many of her peers, close analysis of her attached notes showed that she had a high level of understanding of her preferred topic "The Human Body" (Ruth is a qualified pathologist). Other preservice teachers copied the approach demonstrated in lectures and tutorials and spread their concepts into neat spatial arrangements on the computer screen, but these maps contained no more detail and demonstrated no greater understanding than Ruth had. She had used the concept mapping tool in a different way, but was as successful as the rest of her peers. Ruth's prior experience probably influenced the way in which the tool was used, but this did not affect the final outcome. Her knowledge was just organised in a different way.

**Concerns about the technology**

Many students expressed concerns about the technology and these related to two issues the use of an unfamiliar computer system (even though all had completed a 15 week
subject with the same computer system), and anxiety associated with the use of computers.

The fear of technology is expressed by Sally (aged, 20) who stated:

> a lot of people (students) are scared of computers and even if it is something simple they want to be reassured that they're doing it right because they're scared that it's a big technological thing and it's going to jump up and bite them.

Val (aged, 35) stated that "Initially I found it a little daunting because I am not familiar with the Macs" but later in the interview she stated:

> that it really is something that we ought to be forced to do in more things. Whether or not we like it or are comfortable with it, I think it is the way of teaching and whilst I would certainly be more comfortable doing it at home, I think it is a necessary part of our teaching way.

Thus she was prepared to work outside her zone of comfort as she could see that it would benefit her in the future.

Younger preservice teachers also expressed similar concerns and Danielle (aged, 20) said:

> I had reservations before I began because I don't like computers and I'm well known for that, but the spatial concepts really appeal to me and the note behind them.

Like Val, Danielle overcame her initial fears and found that she could effectively use the software.

Once the initial concerns were put to rest, the students were able to concentrate on the process of constructing their concept map and as Helen (aged, 28) stated:

> I thought I would have problems because I am technophobic, I'm scared, and if I have my way, I would rather usually write or go to the bookshelves in the library rather than use a keyboard.

At the end of the interview, however, she stated "I've enjoyed it.... I'm just not so technophobic now."
Use of the tool to construct concept maps

The interview transcripts revealed that two basic approaches were used. The first approach was to start with a main concept at the top or on the left hand side of the screen, "brainstorm" as many concepts as possible and locate them anywhere on the screen. Later these concepts were rearranged into a pattern that had meaning for the student. Then links were drawn among concepts; finally notes were added. Ten of the 14 students interviewed used this approach. All of these students had preferred learning styles that were either accommodators (doing, involved, impatient, people) or divergers (imaginative, emotional people). Further investigations with a larger sample would need to be made to further clarify this issue about any relationship between preferred learning style and the way learners construct concept maps.

As Sally (aged 20) said:

I created a box with the idea in it and then I had a few more ideas that were related to that so I just created a lot of concepts on the page, not necessarily in any particular order and then I moved them around so that they were in some sort of sequence and by moving them around, I think, I kind of decided that some of them needed to change so I erased those concepts and put in new ones that were better related to the topic and then I kind of put links in and then the notes.

Figure 7.5 shows Sally's map. Her concept map contains concepts and names of people as well as some questions. It is spatially organised and contains notes which explain her concepts and links.
Mary B (aged, 38) used a similar approach to Sally and said that she:

"...started with the concept tool first. I put them where I thought they would better connect. Then I used the link tool. I've sort of gone back and forth a lot."

Again her map contains comprehensive notes that relate to her links and concepts.
Students who used the second approach arranged a few concepts around their main concept and then added notes and links, then more concepts and links. At first glance, it appeared to be less efficient but the maps produced were as comprehensive as those produced by the first approach. Two of the 14 students interviewed used this approach.

Kerry W. (aged, 35) said:

I wrote the first concept, typed in the first few concepts and then I wrote notes. I typed in some more concepts, modified a few to make it clearer, made the concepts more clear and then I came back and put the links in and I thought about wording the links and then I thought, no that's something that I have to go home and have a good think about, so then I started writing the notes, typing the notes out.

Figure 7.7 shows her concept map and shows that the notes behind the concepts were comprehensive. Kerry and Julie were the only two preservice teachers interviewed who constructed their concept maps by arranging clumps of concepts around their main concept and then adding notes. It was noted that both had the same preferred learning
style (Assimilator - conceptual, less practical people). Once again further investigation of this issue with a larger population is warranted.

Figure 7.7: Kerry W's concept map

The method used varies a great deal but the different methods did not necessarily lead to very different outcomes.

**Thinking processes**

Many students realised that the concept mapping tool was a thinking tool and as Helen (aged, 28) said:

I started to create a concept and tried to actually use the tool to make the join, the line, the links. Later on I realised it would be better just to get it all out of my brain and then arrange it, use the tool.

The following quote from Leanne (aged, 35) shows that she took a similar approach and said:
well I basically sort of just dived in and I knew, because I had my topic sort of in
my mind and I hadn't done anything on paper whatsoever so I walked in there
basically with an idea in my head and went to work and sort of exploded this
costume map about my topic of communication.

Later in her interview Danielle (aged, 20) summarised this aspect of the tool when she
said that "It helps me clarify my own thoughts ...". For her, use of the computer-based
tool seemed to become obvious and the technology moved into the background as she
used the tool as a thinking tool.

**Features of the tool that helped them to construct their maps**

The preservice teachers described various features of the concept mapping tool that they
felt helped them to construct their concept maps. These features are discussed in the
following section.

**Hidden notes**

The feature of the hidden notes behind concepts was mentioned in four interview
transcripts. As Adele (aged, 20) stated, "The notes are good 'cause you can have it
behind there without having paper all over the place." Mary (aged, 38) agreed with her
but pointed out that, "I liked the way that when you had a note behind it, it had a double
band around it." She liked this feature because when she came back to use the application
again she could see at a glance which concepts and links had notes attached. All of the
students interviewed liked the note feature because it left room on the screen to add more
concepts, and as Ruth (aged, 30) said "there's heaps of room...".

Sally (aged, 20) probably best summarised the benefits of this feature when she stated:

> It's a very neat way of getting the notes behind the concepts. I really liked that idea
so that you could have the information about it and the thing of being double lines
when it's got a note behind it because then I can say OK, that's the concept that I've
been working on. OK, here's another concept which I haven't done anything on yet
which I have forgotten about. Whereas if you are writing with pen and paper and
you've got the notes on a separate sheet and you've got the concepts on another, it's
not so easy, it's not so visually clear, straight off.
Other features mentioned were the ease of use and appeal of the final printed copy. As Adele (aged, 20) said, "...it'd be easier...that's why the print out's good because then you can see what you've written" and Kerry (aged, 35) agreed when she said "...certainly looks better... it's more presentable.

Barbara (aged, 48) said that:

it was really self explanatory once you got involved in it so it was just a matter of clicking on concept and actually making the concept itself and then as I said it was pretty simplistic to just go through all those things. The hardest part for me was figuring out what I was going to do.

Kerry's (aged, 35) transcript supported Barbara's comment when she said:

the tool bar is good instead of having to use a pull down menu. Just having it there to click on is heaps easier than having to pull down all the menus and trying to work out where it is. It's less, it's harder to make a mistake really because you've got that big box to click on.

Another feature mentioned in 7 of the 14 transcripts was that it was easy to edit and revise their maps. As Val (aged, 35) stated:

I'm more comfortable with a pen and paper but I'm not sure whether it would be time effective. The beauty of this thing is that you can put it on, rub it out, change it around as many times as you want to.

Revision of concept maps

As the students became more experienced they realised that they needed time to revise their concept maps and some of this time had to be spent away from the computer. The following approaches emerged from the transcripts: the use of pen and paper at home (5 transcripts); writing over a current print out of the map (5 transcripts); narrowing down the maps and making the concepts more specific (11 transcripts).

One reason for using pen and paper at home was lack of access to a suitable computer (8 transcripts) and as Kerry S. (aged, 20) stated, she worked at home and liked to:
write in link notes at home so when I get into the computer room it doesn't take me as long to do it because access is a bit hard but if I had it at home I wouldn't have used pen and paper I would've just done it straight on there.

Julie (aged, 32) felt that she needed to work at home and that:

the final product was a result of like numerous and I mean numerous pen sessions where I was sitting down with paper and mapping out where I wanted to go. When I look at like the final product and the first one I did, it's, they're chalk and cheese because the first one was really where I wanted to be at the end and I had to work backwards and start from the beginning and work to where I wanted to go... it took me a lot of time at home sitting with numerous amounts of scrap paper and working out where I wanted to get to because I think I knew too much about the subject in the beginning.

Julie chose the Human Body as her topic as she is a qualified nurse. However, she soon found that when one has a great deal of knowledge about a subject it can be difficult to present it as a manageable whole to others.

While Leanne (aged, 35) also invested a great deal of time at home revising her map, she realised that if she had access to the hardware and software at home the task would have been easier. She stated:

I did it with pen and paper but what I found was I had to have a piece of paper for this note and then some piece of paper for link notes and a piece of paper for this; whereas if you're actually doing it when you're at the computer you haven't got all these sort of things. When I was trying to just input it onto the concept map I worked on the text in particular, but when I went to input it I sort of was still rifling through sheets of paper here and there and trying to find notes ... The tool keeps it nice and neat and you know where everything is and you can go from one to the other and check back and that and it's very simple, it stays organised for you.

Ruth (aged, 30) came into the computer room on many occasions and revised her map in this room. She stated:
You just zip it around and change a whole idea there and then because I find as you're developing a concept map you start off small and the more comfortable you get with it you just keep going broader and broader and you get better ideas. The first part you always start off, you go, 'Oh yuk, cross that out and start again'. Whereas this it's an evolving thing all the time. You're updating it all the time and it's getting better and better whereas paper because it's restrictive you tend to be restricted cause you can't be bothered having this mess everywhere but you just tend to go in the direction that you first thought of whereas this way you can change on the spot.

Danielle (aged, 20) also went to the computer room to revise her map and said that:

after two weeks of using this tool to revise my map I really quite like it, because the concepts can be moved around and you don't have to rub out and take extra effort. It's just easy to manipulate what's going on so I wouldn't use a pen and paper at all.

Narrow down concepts and revising definitions

Ten of the 14 interview transcripts mentioned the need to narrow down their concept maps to a more manageable size and to re-name concepts so that their meaning is clearer. During her revision process Loretta (aged, 32) "... changed the names of the concepts to be more scientific rather than general terms." She felt that these changes developed her map into a more powerful and integrated representation of the knowledge that she wanted to teach to children. Adele (aged, 20) also narrowed down her concepts and she described how she achieved this.

First off I wiped out the longitudinal waves and speed of sound and then I put some notes behind the how sounds travel and sound vibrations ones and I was trying to modify it so it's more suitable for teaching than to teachers which I was really doing last week cause I was just getting it out of a book. I'd narrowed down the main concepts.

Figure 7.8 shows Adele's map undergoing the modifications she discussed.
Figure 7.8: Adele's concept map undergoing modification

When something makes a noise, it makes the air move. It makes sound waves in the air. The sound waves go to your ears and you hear the sounds. If you put your hands over your ears you cannot hear very well because the sound waves cannot get to your ears. Sound

However the process of narrowing down concepts and revising the map was not an easy one as the following transcript from Barbara (aged, 48) shows.

I was going to do my concept map on Australia so talk about huge, ... that's what I found through the actual process of seeing it visually in front of me on the, using the concept mapping tool. I thought no way, there's no way that I could cover this huge thing in six weeks or even 12 or maybe even 12 months. You know that was just what I thought and it was actually visually seeing that by using the tool that really brought it home to me that no way, you've got to narrow this focus it's much too broad.

Barbara continues to explain that the process was very demanding.

That was a very painful process because I had to keep narrowing, narrowing, narrowing, narrowing, but I found that the tool was very good for that because I could immediately see as soon as I put it there visually in front of me. I could
immediately see, that no, no, there's too much here, I've got to get further into
this and narrow it down further. So I thought that was excellent for that because I
am visual so I need to be able to see that.

In the end she was satisfied with her final map but it took her a great deal of effort. Barbara worked informally with Ruth who also made use of the computer laboratory in her spare time to revise her maps. Like Ruth, Barbara was familiar with the process of mind mapping which uses a much less disciplined approach to the creation of semantic networks. It appears that she had more difficulty narrowing down her concepts because she was more comfortable with this less formal procedure. The process of forcing students to produce a map that included concepts that were suitable for primary school and could be dealt with during approximately 15 hours of instruction may have forced her to become more selective in her choice of concepts and to integrate them into a more powerful and comprehensible framework. Figures 7.9 and 7.10 show Barbara's first and second maps. It can be clearly seen she narrowed down the focus of her map.

Figure 7.9: Barbara's first map
Six transcripts mentioned the need to see the on-screen display of the concepts and how this visual display assisted them to see faults in their maps. As Kerry S. (aged, 20) said:

I feel it made my unit better because the visual aspects made me see that I wasn't using everything to do with electricity.

Sally (aged, 20) changed the arrangement of her concepts several times before she was satisfied. She stated:

I keep changing where my main concept was from the top to the side and back again, because I just want to have it so that it looks, so that I can follow it with my eyes so that I can see the sequence that I'm talking about. I want what's on the screen to look like what's in my brain.

Leanne (aged, 35) also altered the structure of her map and described these changes as follows.
I've gone from having my main concept at the top and working down to having my main concept at the side and sort of having a top half and a bottom half and I found I could organise my concepts better by changing the overall format. I've also changed the names of some of the concepts to what I consider to be more related to the activities and the content when I've tried to explain them.

**The challenge of writing link notes**

Four of the transcripts mentioned that the link notes were often difficult to write and added another layer of complexity. As Kerry (aged, 20) states:

I thought it was all perfect and then when I was actually writing the link notes that just didn't make sense having the arrow that way because you can't explain it.

She then continued to describe the revisions that were needed when she stated:

I had to look up some things but it makes you really think how to write short link notes as well but how to make the concept links clear. It's hard to explain how they link.

These findings support the previous work of White and Gunstone (1992) who asserted that the writing of links was one of the most 'irksome' tasks for learners.

**Time to think about the map and preparation**

The more conscientious students took time to develop their maps and to find more resources so that they could come to the computer room well prepared. This meant that they could efficiently use their time when they were in the computer room. As Loretta (aged, 28) states, "It took time to develop the actual concepts but not the actual concept map itself.". Kerry (aged, 20) elaborated on this point when she stated, "You've got to do some work before you go there." Also she asserted that "you have to know everything to put in the concept map so really it's prerequisite knowledge for what you're going to do in a teaching unit."

Sally (aged, 20) also spent time gathering information from a variety of sources and she described how she did this.
I've spent a little bit of time especially when I went home and I got to look at my books on my bookshelf so I found a really good space atlas and a few other things and I work at the Science Centre where they've been playing a comet video, a video about the history of Halley's comet. So I've been paying attention to that so I'm more conscious of things about comets at the moment and I specifically look for information on comets although not so much meteors because they're a bit harder to get information on.

Others liked to work at home and to spend time away from the computer laboratory. Five transcripts from mature age students (aged 32 and over) mentioned this point. The following transcripts from Val (aged, 35) and from Kerry W. (aged, 35) are examples.

Val said, "I would have preferred to have done this at home in the privacy of my own scene with my own known ways of doing things. " Val went home and did some homework and stated:

I got to some fairly solid ideas I thought that I was comfortable with. Then I brought my notes in this morning and worked on a concept map. Other than the physical setting out on the page, I am not unhappy with it.

Kerry also wanted also to work in this way and said:

I'd like to take it home because I need, I really need to think before I can sit. Like an hour's not long enough to sit there and do what we have to do and when you finally sit down and your thoughts have melded and you're ready to type, nearly time to go. So I'd rather spend a lot more time sitting there with it, over 2 or 3 hours and a bit more quiet at home would be best.

Barbara (aged, 48) revised her map at home as well as in the computing laboratory. She liked to work with pen and paper as well as the computer because she felt that:

There's something that happens between my head and my hand that helps me and it's probably a psychological thing. It just helps me, I feel comfortable. I mean that's my era, pen and paper so I feel comfortable doing things...when I sat down with pen and paper, I thought, aha, this is the way the arrows go and because sometimes that was a problem for me.
Barbara continues:

If I had it at home (the hardware and software) I would have used it. I wouldn't have bothered about pen and paper as much.

She was more comfortable with pen and paper but spent extra time in the computer laboratory with Ruth so she was not entirely dependent upon one mode of operation. She moved back and forth between the computer and pen and paper. This is similar to the way in which many writers use word processors. That is, they print a draft copy of their work and then edit the paper version before they return to the on-screen version.

**Other uses of the concept mapping tool**

Several other uses of the concept mapping tool were suggested by students and these included use as a curriculum planning tool that can assist teachers to plan units of work and use as a device for assessing children's ideas about topics taught or about a topic that is about to be taught. A common idea mentioned was the use of the concept mapping tool to help learners make visual displays of their ideas about curriculum topics.

For example Ruth (aged, 30) suggested that:

Rather than just a concept map, I could see that the application might cover a unit eventually, rather than just as the definition type map of the concept.

Danielle (aged, 20) took this point further when she said, "so I'd use this not only in planning but in implementing a unit".

Leanne (aged, 35) argued that:

it's certainly an effective tool for using to plan a unit because it makes you identify all the concepts that are involved, it makes you think of how you can teach them.

Later in the interview she explained how she used this tool to help her to construct a teaching unit.

I haven't actually started writing up any of the unit yet but it's not going to be difficult because I've done it all, if you know what I mean. It's all, in order to get this concept map working right, you have to go through all those things, what are the outcomes on, which skills, which processes does this activity address, am I
addressing designing and making using technology and investigation? Am I doing all the things required by the syllabus. You look at what concepts and how you're going to teach them, but you've also got to look at whether the activities that you planned are achieving the broad syllabus sort of outcomes... I think I'll have one really good unit.

Leanne (aged, 35) also thought that it would be a good tool to use with children. She explained that it:

... gives them a way of recording their thoughts. If you don't, there's no way for you to capture them, you can lose them. And so this is one way of recording them particularly if you're introducing a big topic and want to get their initial responses to it and then maybe look at where their interests lie; or where there's holes or where there's misconceptions. A lot of the time particularly when you're looking at scientific concepts, they might have some really way off ideas on how things fit in together and you can identify those so that then you can address them in your teaching.

Leanne's ideas show that she understands that students have misconceptions and it is important for teachers so be aware of these and to address them in planning learning activities. She views the concept mapping tool as an effective way of recording children's ideas.

Barbara (aged, 48) also feels that the tool could be applied to children and states that:

it's just a way to ask people to put on paper, to put their brain on paper for you I suppose and then you can develop something that assists the bulk of the kids or you can develop a range of activities that will assist different ways of thinking because it's all valid, it's just different and there's nothing wrong with different. If the teacher doesn't know how people are thinking, you can't cater for that.....

However, she recognised that it took a great deal of effort to achieve satisfactory results and she states that:
this has been a very stretching sort of an exercise and that's a good thing and if that, if you could do that in the classroom, I think there will be all sorts of benefits because it doesn't only apply to science obviously.

Helen (aged, 28) held similar views to Barbara and said that:

I would say use it as a beginning and end thing to see where we are at the beginning to see where we're going and then the children could add on any little side tracks that they might have.

Later she said, "I think concept mapping's a great idea because it just gets you, it forces you to put the ideas from your head onto paper or onto a computer screen."

The use of the concept mapping tool as a curriculum planning tool has been reported by Ferry (1996) and the use of concept mapping as a tool to "probe understanding" has been reported by White and Gunstone (1992).

**Summary of the data relating to the use of the improved version of the concept mapping tool.**

The statistical data showed that 90% of preservice teachers did not change the topic of their second map and this may indicate that they were committed to producing a good map about their chosen topic. This interpretation is supported by the fact that the topic chosen by each preservice teacher was to be the focus of a science unit to be taught in a primary school later in the year. When the first and second concept maps were compared the following improvements were identified: greater use of link notes and concept notes; increases in cross-links; and increases in levels of hierarchy. However, the number of concepts on the maps did not show a significant increase and this is interpreted as an indicator that the preservice teachers concentrated on refining concept names and on improving the structure of their maps so that the second map formed a more powerful integrated framework of concepts.

The interview data supported the interpretation of the statistical data. There were initial concerns over the concept mapping process and the use of the concept mapping tool, but the instructional process helped to allay these fears, especially those associated with the
use of computers. Indeed the technology soon became transparent and the preservice teachers could then focus on the construction of their concept maps.

As the preservice teachers became more familiar with the software and the process of concept mapping, they began to use the tool in different ways. Some preferred to use a brainstorm approach and put all of the concepts on the screen first before rearranging them into a hierarchical framework that illustrated their understanding of the relationship among the concepts. Then they added links and notes. Another group preferred to work in "chunks" and they added a few concepts at a time. These were organised into a meaningful framework that contained links and notes. They then added more "chunks" to this framework. A small number also used the tool to add concepts, notes and links in a more random fashion. However, in most cases there was little difference in the final map produced. It appears that the concept mapping tool helps them to visually organise knowledge and this may have been one of its strengths. The hidden notes were considered a strong feature of the tool as the notes allowed the preservice teachers to add another dimension to their maps. It was also noted that the way in which the preservice teachers used the tool to construct their concept maps may be related to their preferred learning style.

When preservice teachers revised their maps they took time away from the computer to gather more information. Also they mentioned that thinking and preparation time were important parts of the revision process. Most preservice teachers used pen and paper to revise their map and often they wrote over print outs of earlier versions of maps. This strategy is similar to the way many people work with word processors as often they edit printed drafts away from the computer (Hedberg, 1990b). However, those that had access to the computing laboratory did most (but not all) of their revision on screen.

The preservice teachers mentioned that they revised their maps by adding more notes and links (which they often found challenging). Considerable time was spend in "narrowing down" their maps because their original maps contained concepts that were too broad. Thus, many concepts were re-named to be more specific in meaning. Also concepts were spatially reorganised into more integrated knowledge structures.
The preservice teachers suggested several other uses of concepts maps in school settings and this response is interpreted as an indicator that they value the concept mapping tool as a flexible cognitive tool that has application in classroom settings. In the conclusion to his study Rye (1995) reported that the students involved also valued concept mapping "as a tool to think and remember" (p.271). Thus, concept mapping tools appear to be valued by both learners and instructors.

**Use of the improved cognitive tools that assisted learners to analyse graphs and tables**

This section of the results looks at the ways in which information about rainforest destruction was accessed and how the preservice teachers used the cognitive tools that were available to assist them to analyse and synthesise information presented in text, tables and graphs. It begins with the data from the tracking program and is followed by interview data, and then by detailed analysis of the concept maps produced.

The information about rainforest destruction was used over 2 weeks. During this time preservice teachers received 2 formal lecture/demonstrations and used the software during a one hour tutorial session. Table 7.6 shows how the formal instructional time was organised and when the data were collected.

**Table 7.6: Organisation of instruction and data collection**

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture</th>
<th>Tutorial</th>
<th>Data collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to the software 1&lt;br&gt;30 minutes</td>
<td>None</td>
<td>No data collected</td>
</tr>
<tr>
<td>2</td>
<td>Introduction to the software 2&lt;br&gt;30 minutes</td>
<td>practice- 10 minutes&lt;br&gt;use- 50 minutes</td>
<td>tracking data&lt;br&gt;journal entries&lt;br&gt;concept maps</td>
</tr>
</tbody>
</table>

**The data from the tracking program**

Table 7.7 displays the average frequencies and times spent at the various sources of information. The standard deviations, and maxima and minima are included so the reader can appreciate the wide variation in use of these sources of information.
Table 7.7: Tracking data showing user access to information

<table>
<thead>
<tr>
<th>Information sources</th>
<th>Av. freq</th>
<th>S.D.</th>
<th>min.</th>
<th>max.</th>
<th>Av. time mins</th>
<th>S.D. mins</th>
<th>min.</th>
<th>max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
<td>.4</td>
<td>1</td>
<td>3</td>
<td>.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Text &amp; glossary</td>
<td>9</td>
<td>4.6</td>
<td>1</td>
<td>21</td>
<td>7.9</td>
<td>4.3</td>
<td>2.4</td>
<td>20.0</td>
</tr>
<tr>
<td>Table</td>
<td>4</td>
<td>2.8</td>
<td>1</td>
<td>11</td>
<td>3.5</td>
<td>2.6</td>
<td>0.8</td>
<td>10.2</td>
</tr>
<tr>
<td>Graph 1</td>
<td>3</td>
<td>1.6</td>
<td>1</td>
<td>6</td>
<td>2.3</td>
<td>1.1</td>
<td>0.3</td>
<td>5.5</td>
</tr>
<tr>
<td>Graph 2</td>
<td>3</td>
<td>2.1</td>
<td>1</td>
<td>8</td>
<td>2.1</td>
<td>1.4</td>
<td>0.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Graph 3</td>
<td>1</td>
<td>.8</td>
<td>1</td>
<td>3</td>
<td>.6</td>
<td>0.3</td>
<td>0.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>construction tools</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questions</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>12</td>
<td>4.5</td>
<td>1.1</td>
<td>3.1</td>
<td>7.7</td>
</tr>
<tr>
<td>Concept map tool</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>11.6</td>
<td>5.6</td>
<td>5.9</td>
<td>24.9</td>
</tr>
</tbody>
</table>

Table 7.7 shows that the text was the primary information source for most preservice teachers, and they spent most of the time using the concept mapping tool to construct their maps. Much of this "construction" time may represent thinking and manipulation time involved in the process of knowledge construction.

The data describing the total time for the task is displayed in table 7.8

Table 7.8 Times spent using the software

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>32.6 minutes</td>
</tr>
<tr>
<td>S.D</td>
<td>8.5 minutes</td>
</tr>
<tr>
<td>Max. time</td>
<td>51.9 minutes</td>
</tr>
<tr>
<td>Min. time</td>
<td>19.6 minutes</td>
</tr>
</tbody>
</table>

The wide range of times spent using the software reflects the variation that would be expected from a group of adults who were engaged in a task that was not constrained by a minimum time frame. This is also true in real-life where people often vary a great deal in the effort and persistence they show towards a task. However, it can be misleading to interpret the data at face value and it is probably best to use it to confirm or refute data from other sources such as interviews and the concept map analysis. For example, the raw data do not tell us if the subject who took 51.9 minutes spent any more time on task than the person who took 19.6 minutes. One may have spent time talking to peers (in a
productive or non-productive manner), while the other focused entirely on the task at hand.

Regression analysis of the relationship between the number of times a person looked at the sources of information (independent variable) and the total amount of time spent using the application (dependent variable) showed that the relationship was significant (F(1,79)=39.34, p<.00001, r²=.335). Thus changes in the independent variable (frequency) could account for 33.5% of the variation in the dependent variable (time). However the relationship is more complex than simple frequency and other factors such as motivation, time off task, thinking time and navigation need to be considered. Caution in interpretation is needed as all that can be really stated is that the frequency of use may predict the time a person spent using an information source.

Regression analysis of the relationship between frequency of use of the concept map tool (independent variable) and the time spent using the tool (dependent) variable showed that the relationship was not significant (F(1,79) =.472, p=.49). One interpretation of this finding is that the concept mapping tool was a knowledge construction tool and preservice teachers would normally use it for a sustained period of time. Therefore they would only temporarily exit the tool to seek out some specific information that they needed and then return to complete their task. Interview transcripts discussed earlier in this chapter support this interpretation.

Table 7.9 below displays the results of regression analysis for the other variables.

Table 7.9: Regression analysis for the relationship between frequency (independent variable) and time (dependent variable) for the various sources of information

<table>
<thead>
<tr>
<th>Source of information</th>
<th>df</th>
<th>F</th>
<th>p</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text</td>
<td>79</td>
<td>132.9</td>
<td>.0001</td>
<td>.6</td>
</tr>
<tr>
<td>Table</td>
<td>79</td>
<td>175</td>
<td>.0001</td>
<td>.7</td>
</tr>
<tr>
<td>Graph 1</td>
<td>79</td>
<td>76.3</td>
<td>.0001</td>
<td>.5</td>
</tr>
<tr>
<td>Graph 2</td>
<td>79</td>
<td>56.9</td>
<td>.0001</td>
<td>.4</td>
</tr>
<tr>
<td>Graph 3</td>
<td>79</td>
<td>29.1</td>
<td>.0001</td>
<td>.3</td>
</tr>
<tr>
<td>Questions</td>
<td>79</td>
<td>13.3</td>
<td>.0005</td>
<td>.1</td>
</tr>
</tbody>
</table>
The table shows that the relationships between these variables were significant and the variation in the frequency of use predicted the total time they spent using the source of information (see the $r^2$ column). However, as discussed previously, caution is needed in interpreting these findings. All that can be confidently stated is that a relationship exists but there are other factors involved.

**Investigation of Hypotheses 3.6.1 and 3.6.2**

Multiple regression analyses were used to ascertain if there were any relationships among the independent variables of attitudes to computers, gender, age, preferred learning style (based upon Kolb's four learning styles), and the dependent variables of the time spent in using specific screen of information, and frequency of subject referrals to specific screens of information.

**The independent variables**

The descriptive statistics for age and gender are displayed in table 7.10 below.

*Table 7.10: Descriptive statistics for age and gender*

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>S.D.</td>
</tr>
<tr>
<td></td>
<td>24.1</td>
<td>6.1</td>
</tr>
<tr>
<td>Gender</td>
<td>females</td>
<td>males</td>
</tr>
<tr>
<td></td>
<td>N=68</td>
<td>N=12</td>
</tr>
</tbody>
</table>

The attitude to computers instrument contained 30 items. Fifteen were positively worded, and 15 negatively worded (these were reverse scored). There were four Likert ratings associated with each question. These ratings were labelled strongly agree, agree, disagree and strongly disagree. Each subscale consisted of 10 items 5 were positively worded and 5 were negatively worded. The test-retest reliability was .78 which is acceptable (Oppenheim, 1992). Table 7.11 displays the summary statistics of the responses to this instrument. A high score is equivalent to low anxiety.
Table 7.11: Responses to survey on attitude to computers

<table>
<thead>
<tr>
<th>Scale</th>
<th>Mean</th>
<th>S.D.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer anxiety</td>
<td>34.5</td>
<td>4.1</td>
<td>23</td>
<td>40</td>
</tr>
<tr>
<td>Computer confidence</td>
<td>30.4</td>
<td>4.7</td>
<td>21</td>
<td>40</td>
</tr>
<tr>
<td>Computer liking</td>
<td>27.7</td>
<td>4.7</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>Combined</td>
<td>92.6</td>
<td>12</td>
<td>59</td>
<td>113</td>
</tr>
</tbody>
</table>

The maximum scores for each subscale is 40 and the minimum is 10. The maximum for the combined scores is 120 and the minimum 30. The mean score for computer liking is lower than the other scales and a paired t-test showed that the differences were significant. Table 7.12 below summarises the results of these analyses.

Table 7.12: Paired t-test results for subscales

<table>
<thead>
<tr>
<th>Scales compared</th>
<th>df</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>computer anxiety - computer liking</td>
<td>79</td>
<td>16</td>
<td>.001</td>
</tr>
<tr>
<td>computer confidence - computer liking</td>
<td>79</td>
<td>6.2</td>
<td>.001</td>
</tr>
</tbody>
</table>

The significant difference in the subscales suggests that the preservice teachers may claim to be confident with computers and claim not to be anxious but this does not mean that they like using them or like computers. Indeed this finding is supported by Danielle (aged, 20) who in her interview transcript mentioned that she does not like computers but feels that she is a competent user.

Responses to Kolb's learning style instrument (displayed in table 7.13) can be plotted on a four quadrant map and the dominant quadrant identified (see Figure 7.11 on the following page).

Table 7.13: Responses to Kolb's learning style inventory

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-accommodator</td>
<td>31</td>
</tr>
<tr>
<td>2-diverger</td>
<td>29</td>
</tr>
<tr>
<td>3-assimilator</td>
<td>12</td>
</tr>
<tr>
<td>4-converger</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>80</td>
</tr>
</tbody>
</table>
Most responses indicated that their preferred learning style was in quadrant 1 or 2. A retest taken after one month showed that the correlation between preferred quadrants from one test to the next was .72. This figure is similar to the test-retest reliability figures of .73 quoted by Sewell (1986).

As the test-rest reliability is barely acceptable (Oppenheim, 1992), caution is needed in interpreting these findings. The distribution of the majority of responses among accommodators and divergers may relate to career choice as research by Kolb and Goldman (1973) found that the preferred learning styles of students who planned to graduate in a major field matched their field of study. Furthermore, recent research with preservice teachers (Reiff and Powell, 1992) supports the interpretation that the majority of preservice education students are likely to have a preference towards learning that is based upon active experimentation and concrete experience. Also Ellsworth (1990) reported that concrete experience and active experimentation learners are more likely to be comfortable with electronically mediated learning. The data from this study do not support either of these researchers as regression analysis of the relationship between the independent variable of learning style and dependent variable of attitude to computers
score showed no significant relationship ($F(1, 79) = 1.7, p=.202$). The interview data suggested that some preservice teachers have preferences for specific forms of information, but this may not be associated with any of the previously mentioned factors. The absence of a significant finding for the independent variable of learning style may still warrant further investigation as some researchers (Ellsworth, 1991; Reiff and Powell, 1992) have reported significant findings in different contexts.

Table 7.14: Preferred learning style of preservice teachers interviewed and the information sources they preferred to use

<table>
<thead>
<tr>
<th>Name</th>
<th>Kolb Quadrant</th>
<th>Preferred forms of information 1-most preferred.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danielle</td>
<td>1</td>
<td>1 text, 2 graphs</td>
</tr>
<tr>
<td>Mary</td>
<td>2</td>
<td>1 text, 2 tables</td>
</tr>
<tr>
<td>Sally</td>
<td>1</td>
<td>1 text, 2 either graphs or tables</td>
</tr>
<tr>
<td>Adele</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>Julie</td>
<td>3</td>
<td>1 text, 2 graphs</td>
</tr>
<tr>
<td>Ruth</td>
<td>2</td>
<td>1 text, 2 either graphs or tables</td>
</tr>
<tr>
<td>Val</td>
<td>1</td>
<td>1 text, 2 graphs</td>
</tr>
<tr>
<td>Barbara</td>
<td>2</td>
<td>1 text, 2 graphs</td>
</tr>
<tr>
<td>Kerry S</td>
<td>1</td>
<td>1 graphs &amp; table</td>
</tr>
<tr>
<td>John</td>
<td>1</td>
<td>all</td>
</tr>
<tr>
<td>Chris</td>
<td>2</td>
<td>1 text, 2 graphs</td>
</tr>
<tr>
<td>Joanne</td>
<td>2</td>
<td>1 text, graphs</td>
</tr>
<tr>
<td>Leanne V</td>
<td>2</td>
<td>1 text, 2 graphs</td>
</tr>
<tr>
<td>Helen</td>
<td>2</td>
<td>1 text, 2 graphs</td>
</tr>
<tr>
<td>Kerry W</td>
<td>3</td>
<td>1 text, 2 tables</td>
</tr>
<tr>
<td>Melinda</td>
<td>1</td>
<td>1 text, 2 graphs</td>
</tr>
<tr>
<td>Loretta</td>
<td>1</td>
<td>1 tables, 2 graphs</td>
</tr>
<tr>
<td>Leanne</td>
<td>4</td>
<td>1 text, 2 graphs</td>
</tr>
</tbody>
</table>

Relationships among the independent variables

It has already been shown that there was no significant relationship between learning style and attitude to computers. Multiple regression was used to determine if there were any relationships between the variables of age and gender, and the variables of learning style and attitude to computers. No significant relationships were found and the summary statistics are reported in table 7.15.
Table 7.15 Summary statistics for multiple regression analysis of relationships among variables

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Dependent variable</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>gender, age</td>
<td>learning style</td>
<td>79</td>
<td>.023</td>
<td>.97</td>
</tr>
<tr>
<td>gender, age</td>
<td>attitude to computer</td>
<td>79</td>
<td>.1</td>
<td>.87</td>
</tr>
</tbody>
</table>

Table 7.16 displays the results of multiple regression analyses used to ascertain if there were any relationships among the factors of gender, age, total score on attitude to computers scale and preferred learning style (based upon Kolb's four learning styles), and the dependent variables of time spent using specific information screens and frequency of use of specific screens of information. It shows that there were no significant relationships among these dependent and independent variables.

**Table 7.16: Results of multiple regression analysis of other factors examined**

<table>
<thead>
<tr>
<th>Independent variables (listed below)</th>
<th>Dependent variable</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>gender, age, attitude to computers, preferred learning style</td>
<td>time using text</td>
<td>79</td>
<td>.6</td>
<td>.7</td>
</tr>
<tr>
<td>as above</td>
<td>frequency of use of text</td>
<td>79</td>
<td>.3</td>
<td>.9</td>
</tr>
<tr>
<td>as above</td>
<td>time using table</td>
<td>79</td>
<td>1</td>
<td>.42</td>
</tr>
<tr>
<td>as above</td>
<td>frequency of use of table</td>
<td>79</td>
<td>1.7</td>
<td>.15</td>
</tr>
<tr>
<td>as above</td>
<td>time using graph 1</td>
<td>79</td>
<td>1.9</td>
<td>.12</td>
</tr>
<tr>
<td>as above</td>
<td>frequency of use of graph 1</td>
<td>79</td>
<td>1</td>
<td>.39</td>
</tr>
<tr>
<td>as above</td>
<td>time using graph 2</td>
<td>79</td>
<td>.3</td>
<td>.86</td>
</tr>
<tr>
<td>as above</td>
<td>frequency of use of graph 2</td>
<td>79</td>
<td>.6</td>
<td>.66</td>
</tr>
<tr>
<td>as above</td>
<td>time using graph 3</td>
<td>79</td>
<td>.23</td>
<td>.9</td>
</tr>
<tr>
<td>as above</td>
<td>frequency of use of graph 3</td>
<td>79</td>
<td>.22</td>
<td>.8</td>
</tr>
<tr>
<td>as above</td>
<td>time using questions</td>
<td>79</td>
<td>.21</td>
<td>.9</td>
</tr>
<tr>
<td>as above</td>
<td>frequency of use of questions</td>
<td>79</td>
<td>.22</td>
<td>.9</td>
</tr>
<tr>
<td>as above</td>
<td>time using concept map</td>
<td>79</td>
<td>.7</td>
<td>.56</td>
</tr>
<tr>
<td>as above</td>
<td>frequency of use of concept map</td>
<td>79</td>
<td>1.4</td>
<td>.23</td>
</tr>
</tbody>
</table>

The independent variables were gender, age, total score on attitude to computers scale (scores can range from 30 to 120) and preferred learning style (based upon Kolb's 4 learning styles - a category of 1, 2, 3, or 4 for each person).
Thus hypotheses 3.6.1 and 3.6.2 were not supported no relationships were found among the independent variables of attitudes to computers, gender, age, preferred learning style (based upon Kolb's four learning styles), and the dependent variables of the time spent in using specific screen of information, and frequency of subject referrals to specific screens of information.

**Summary of findings associated with the tracking data and the independent variables**

The tracking data can be used with other forms of data (such as observation and interviews) to verify or refute findings, but use of the data in isolation is problematic. While the data serve to identify which information was accessed most often and for the longest time, it doesn't indicate what the preservice teachers did when they were using the information. Also the data may indicate the range of times that preservice teachers took to use the software but it cannot distinguish non-serious attempts. However it may, when combined with other data collected (such as the completed concept maps and the interviews), provide a clearer picture of how the information was accessed.

The data collected from the attitude to computers questionnaire showed that preservice teachers scored lower on the computer liking sub-scales than on the computer anxiety and computer confidence sub-scales. One interpretation is that preservice teachers don't have to like computers in order to be comfortable and confident with them. The distribution of preservice teachers' learning styles reflects the findings of other researchers. However, no significant relationship was found between learning style and preferred form of information.

**Interviews with preservice teachers who used the cognitive tools**

Interviews about the use of the HyperCard™ software relating to rainforest depletion were conducted. A copy of the interview protocol is included as Appendix 8.

The rainforest application contained several forms of information that were supported by a cognitive tool that could be used to assist learners to process the information presented. The preservice teachers interviewed were those interviewed about their use of the concept
mapping tool. The interview transcripts were analysed and the findings presented under the headings of text, table, graphs, questions and concept map.

**Text**

*Figure 7.12: A text screen showing words that were linked to a simple glossary*

Most preservice teachers interviewed (10) skimmed through the text on their first reading; the comment "I've skim read it" from Val (aged, 35) is typical. The text contained key words that were in bold red print and the user could link to a glossary when they clicked on such a word. This feature was mentioned by all of the preservice teachers interviewed (15). Mary (aged 38) thought that, "Kids will pick up on it especially being a brighter colour" and Chris (aged, 25) felt that his curiosity was stimulated and said "I just wanted to find out why the word was highlighted."

However, Helen (aged, 28) saw it as a valuable support tool:

> because you find out exactly what it means at the point of need but you'd need someone to explain that you can click on to those words ... it's a great idea because it's hitting you right when you need it. Go to the understanding straight away.
Julie (aged, 34) agreed and stated "absolutely. I mean if kids were using that, and if they knew that they could simply click on a word in there and they've got it explained to them straight away, they'll learn."

Melinda (aged, 34) claimed that such a tool "saves looking up dictionaries ..." and Loretta (aged, 28) felt that it was useful "for people with English as the second language."

Eight respondents mentioned the use of the glossary when they constructed their concept maps. As Chris (aged, 25) stated, "much information came from the text, mainly the highlighted words."

**Table**

The table displayed a set of figures relating to rainforest depletion. The figures in each column could be sorted in ascending order when the user clicked on the words in the heading. All preservice teachers mentioned this feature and most realised that it was a tool that helped them to process information. As Helen (aged, 28) said "it stops you from having to do it in your head". Kerry (aged, 20) struggled to explain the same idea as her transcript shows.

It does in the way that you get, instead of having to mentally visualise it ... sort it in their own heads like right in front of you. It's easier to picture really, to understand.

Julie (aged, 34) explained it as follows:

It un-jumbles it and I think that makes it clearer to be able to understand it and accentuates it. When you see years to end seven, if you relate that to a child, because that's before you were even out of high school, Nigeria's forests will be finished and they can understand that.

Loretta (aged, 28) also discussed the sorting feature but she had a goal in mind as she wanted to use the information to answer questions. She stated:

I sorted the majority of them. Some of them I had to sort so I can answer the questions. It was easy for me to answer the questions if I sorted these columns.
However, 5 respondents mentioned that the sorting tool could also be used to test hypotheses and as Mary (aged, 38) said "you could start asking 'what if?' questions". Thus, the sorting tool has wider uses than just simple information processing and this feature could be explored during future research projects. It is recognised that other applications such as spreadsheets can also sort columns.

**Graphs**

The graphs contained balloon help that was activated when the cursor was located over the names on the axes labelled "countries" and the numbers at the end of the bars in the graphs. The balloon help on the axes labelled "countries" provided a small coloured map that displayed the location of the country in its home continent. The balloon help on the numbers provided additional explanatory text about the numbers. If the user wanted to disable this feature, (s)he could click on a button labelled "balloons off".

The balloon help on the axes was considered to be an excellent feature but an unexpected comment was that of Chris (aged, 25) who admitted that:

I'm terrible at trying to find where the places are like, I can't remember where they are. Yeh, I think when I first saw it I thought it was a great idea just because I'm not too familiar where they're supposed to be, especially Madagascar, Cambodia. Some of the lesser known places, I wouldn't have a clue where they are.

Another student (Kerry, aged, 20) admitted that many of her peers would "want a world map because we don't know where continents are in relation to Australia." Kerry reinforced this view when she said "I can see the picture of Zaire there (points to a map of Africa). I don't know in relation to the rest of the world where it is." Julie (aged, 34) supported Kerry's view when she said:

I like that because I don't think the children today know or even a lot of adults know enough about world geography and where places are and I just think that's fabulous especially ones that relate back to Australia.

Sally (aged, 20) also liked the balloon help and said:

I already know where most of these countries are already but it's interesting to see that most of them are pretty here, oh, in fact they're all exclusively in either Asia
or Africa except Central America or Brazil. So there's none in so called First World
countries at this point.

Afterwards she realised the theme was "disappearing rainforests" and the data related to
countries (mainly the exploitation of third world countries) whose rainforests were
rapidly disappearing.

Again, Loretta (aged, 28) saw another use for this tool when she stated "I'd even use this
with children that weren't even learning about the rainforest. If they were just learning
perhaps the countries."

Most preservice teachers mentioned that the balloon help for the numbers provided useful
explanatory text. Some (4) thought that the text reinforced what the graph displayed and
others felt that it did more than this because it provided additional information. For
example Leanne V. (aged, 20) felt that it "reinforces what they're actually saying in the
figures" and Chris (aged, 25) supported this view when he said:

It does make the graph more readable, like more user friendly type of thing. And in
mine it just highlights what the graph's saying but in a written term rather than a
visual term.

Others such as Julie (aged, 34) felt that the text added to the meaning and she stated that:

You might just think ten percent is being cleared but when you read the text it says
ninety percent of India's rainforest is already being destroyed so that means if there's
only ten left it just reinforces what the graphs mean.

Sally (aged, 20) took a similar point of view and said:

It's just another way of representing that information to say ok, we've got eighty
five percent left which means that fifteen percent have been destroyed. Yeh, it's
another way of thinking about it which we don't always do.

Loretta's (aged, 28) comment supported all of these arguments when she said:

What that number actually means rather than them having the number there (she
points to 14.3%), I mean so what, what does it mean? But when it pops up it
...actually tells me what it means. It does tell me how much rainforest is actually being destroyed which is really good.

Questions

Table 7.17 displays the questions asked about the data. The questions were designed to encourage preservice teachers to access all of the information. The table also shows the number of correct responses and the source of the answers.

Table 7.17: A list of the questions

<table>
<thead>
<tr>
<th>Q</th>
<th>Text</th>
<th>No. of correct responses</th>
<th>Source of answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Are those countries listed mostly industrialised or third world countries?</td>
<td>69</td>
<td>text</td>
</tr>
<tr>
<td>2</td>
<td>Which country has the largest percentage of tropical rainforests left? Will this rainforest last longer than in other countries?</td>
<td>64</td>
<td>graph or table</td>
</tr>
<tr>
<td>3</td>
<td>The present annual loss of rainforest world wide is 1.8%. The total area of rainforest removed each year is 140 000 km². How many times would Tasmania fit into this area?</td>
<td>68</td>
<td>text</td>
</tr>
<tr>
<td>4</td>
<td>Which country removed the most rainforest and what percentage is now left?</td>
<td>66</td>
<td>graph or table</td>
</tr>
<tr>
<td>5</td>
<td>For some countries the &quot;loss of forest&quot; problem is not seen as an immediate problem and it is put far into the future. They see themselves with a current large debt and need to educate and feed their people. So the rainforest is seen as a 'resource' to be developed. Which countries seem to be in this position?</td>
<td>69</td>
<td>text and graph or table</td>
</tr>
<tr>
<td>6</td>
<td>But for other countries the rainforest will disappear in a very short time. This problem is urgent. Which countries are these?</td>
<td>78</td>
<td>text and graph or table</td>
</tr>
<tr>
<td>7</td>
<td>If the present rate of depletion continues, which counties would not have a rainforest by the year 2020? (The figures are from 1990).</td>
<td>64</td>
<td>graph or table</td>
</tr>
</tbody>
</table>

One explanation for the greater number of errors for questions 2 and 7 may be that both required preservice teachers to compare and order figures, and this created additional cognitive load.

The questions were devised to encourage learners to find information from the text and from either the graphs or the table. Some of the preservice teachers realised that this was the case and as Kerry (aged, 20) said:

the questions were a good way of making sure that one that you looked everything.

You didn't, you'd seen everything that you didn't just flick straight through
everything and said oh yeh, I know that, I know that, I know that. They made you
look at certain things as I said before the table and graphs.

The questions were supplied on a separate sheet of paper as this avoided the problem of
flipping back and forth to the questions while accessing the information, but the
preservice teachers were required to type answers into the on-screen spaces. These
answers were saved in a file under the user's name when (s)he quit the software.

Most questions were worded in such a way that they required the preservice teachers to
read the text and the table or graphs. Preferences emerged. Leanne W. (aged, 35)
preferred the graphs as a primary source of information and stated:

I initially used graphs because I feel like I can interpret graphs reasonably well and I
quite enjoy interpreting graphs. So I was tending to look at the graphs. Then I
actually found the table was easier but I enjoyed the look of the graphs.

Later Leanne mentioned that she didn't need to refer back to the text because she could
remember the parts needed to answer the questions.

Helen (aged, 28) used the text as her main source of information when answering the
questions and she said:

I used the text because I'm a text, I'm a word person, I'm a reader but I backed it up
with, if I've got two sources, I'll always back it up so I check because I don't trust
myself. So knowing there was a graph I'd read it come to an answer and then check
with the graph.

Where possible Helen used the graphs as a means of verifying the information she
obtained from the text. Others used the table and Loretta (aged, 28) used the table a great
deal. She stated that her reason for doing this was "I wanted to get through it quickly".
Her answers were correct except for one and this may reflect her undue haste. By way of
contrast Leanne (aged, 35) preferred the graphs to the table and stated:

I think the graphs are like set out easier to read than the table where it's got every
single one of them on there. That's just breaking it up instead of a whole bunch of
numbers ...
Kerry W. (aged, 35) used both graphs and the table and stated that:

I use the graphs and tables because they present a bigger picture. You didn't have to scroll through them like the text to look for the type you wanted.

All of these comments show that preservice teachers prefer to work with different forms of the same information and it is sensible to allow them to access the forms of information that they are most comfortable with.

Others used a mixture of strategies and Kerry W. (aged, 35) explained that:

the texts to start off with gave the information in your head, basic knowledge to fit the graphs into. If you didn't know about rainforests then the graphs would mean nothing to you.

For Kerry the text provided a context for the information displayed in the graphs and table. Julie (aged, 34) described her approach as a mixture and stated that "I used a mixture, because there was a lot of text to try and take in. That's where the graphs helped." She found that the graphs provided a visual representation of much of the information presented in the text and made it easier for her to integrate the information into a meaningful whole.

**Concept map**

All preservice teachers were asked to use the concept mapping tool after they had looked at all screens and answered the questions.

The concept mapping tool is designed to synthesise information gathered by learners into a powerful integrated network. Several strategies were used but most preservice teachers referred to the text as their primary source of information and to the graphs or the table as a secondary source of supporting information. Eight of the preservice teachers specifically mentioned the text and in particular the glossary words. As Chris (aged, 25) said, "All of my information came from the text, mainly the, the highlighted words." Melinda (aged, 34) took the same approach and she said that:

I referred back to the highlighted words because I thought well they're more likely to be the key concepts. But yeh, I suppose initially it came from my head but then
I wanted to include the things that you had highlighted as well. So it was a combination of them both."

In her case she just arranged on the screen the concepts that were "in her head". Then she referred back to the text. However, Melinda came to this task with a high level of background experience, she had completed three university subjects in environmental education and was a member of a local landcare group. Therefore she may not have needed to access all of the information. Leanne (aged, 31) did not have the same amount of background experience to draw upon and she used a different strategy. As she states "I sort of actually I went back and made notes. I did actually write on a piece of paper."

Julie (aged, 34) also took a similar approach and as she said:

I jotted down my major points. I had a piece of paper next to me and then I just put them down onto the map where I wanted to put them.

She was then asked by the researcher which information sources she used for her ideas for the concept map.

Her reply was:

I got them from the text. I mainly went through the text and looked at main headings and I thought well they would be your major concepts that you'd want to get across... I also went to graph 2 to check some figures on the rainforest but I didn't include them on my map.

Joanne (aged, 20) used the text in a similar way to Julie and also referred to the graphs as she stated:

The text helped me with some of the concepts and if I were doing more notes, like I would like to put notes behind everything and I would go to the graphs and like some of the numbers that go behind there like the greater depletion.

Ten of the preservice teachers also mentioned that they used the table to check on trends in figures and Loretta (aged, 28) summed up this position when she said," I think I like using tables because it tells you the exact figures..." She continues and explains that she was also thinking about the concept map while she was answering the questions and stated:
I was thinking about the whole thing. However, while I was answering the questions and going to the tables, I was also writing notes down on a piece of paper. When I went to develop my concept map I had my notes on a piece of paper so I didn't have to go back.

While Loretta made more use of the table she also made use of the other information sources.

Because all preservice teachers accessed all sources of information before they constructed their concept map, they may not have needed to access all of the information again. Instead they only had to access the information that they needed to complete their map. In Adele's (aged, 20) case she needed to access all of the information and as she stated:

I think they're all needed to make the map ... because that helps you understand all three parts, all parts really because you're looking at the text and by putting it in tables that helps you understand that and then graphing it helps you get a visual picture I guess.

John (aged, 21) explained that he also used all forms of information. He said:

I used the text, tables, graphs. I'm one of these people tends to do things with pen and paper first ...everything from essays down to diagrams. I scribble things out, I erase them, I like to have something almost that's final before I go up to the computer. Now with this program I'm able to muck around with it. Just now I went through the information and flipped back to my map.

Later he explained that he constructed his final map on the screen without the use of pen and paper and this was unusual for the reasons he mentioned above.

These comments demonstrate that the preservice teachers accessed different forms of information in order to construct their concept map. The reasons why they accessed these different forms of information varied but some important reasons may relate to: learner preferences for specific forms of information; learner efficiency in processing the information needed; and previous experience with the subject matter. These issues will be discussed in detail in the next chapter.
The benefits of the concept mapping tool

At the end of each interview each student was given the opportunity to add further comments about what they had done. Most of the comments focused on the use of the concept mapping tool to synthesise information into a meaningful framework. As Julie (aged, 34) stated:

   It makes it all concise. You can see, its a good summary too, without going into reams of writing which doesn't always appeal and you can just put down the main ideas, those ideas may jog your memory.

Sally (aged, 20) expressed it in a different way when she said:

   A concept map actually forces you to think to link the concepts together so if you have the concept map it's actually easier than a summary because you can see the ideas and how they can link them together.

Leanne W. (aged, 35) agreed with Julie and Sally's point of view but showed that she understood the particular importance of links in the construction process when she stated:

   I think the concept mapping tool is extremely good... it's such an effective way of summarising information. Another thing about them that I've developed is this thing about the importance of the links. Where you actually draw your links between concepts is as important as the actual concepts themselves because if you can't show how concepts relate to each then things get confused. For me now it's a matter of building on a known concept and extending it by developing and showing and displaying a link and that leads you on to an understanding of another concept.

Leanne developed an understanding of the importance of links and, though she struggled to express it, she understood that the concept mapping tool could be used to build knowledge.

Later in the interview Leanne revisited a theme she mentioned in a previous interview when she stated that concept maps "help you to see what you know and I'm not talking as an assessment tool so much as just an insight into what kids are thinking." Also she sees the value of talking to children about their concept maps when she says, "unless the child is there to explain where they're at you can lose a lot of their thinking."
Helen (aged, 28) had similar ideas to Leanne but expressed it more succinctly when she said:

I like the idea of doing a concept map at the end because you can see what you've understood, you've put it there so I've latched onto the concept maps for pre and post instruction and I can see I'm learning.

Others thought that it could be a useful assessment and evaluation tool for teachers and as Julie (aged, 34) stated, "It's a really good evaluation, assessment type tool". While this was not the aim of the research project, it does illustrate that the preservice teachers were thinking about how to apply the tool in different contexts.

**Social interaction**

Five preservice teachers mentioned the need to talk to peers while they used the computer to construct their concept maps about the rainforests. As Leanne W. (aged, 35) states:

The sort of social interaction while you're actually engaged in is important. Every time I was in the lab, I felt this need to sort of talk to people while I was making my map which is sort of against all the criticisms they make of using computers. They criticise computers because they can be detrimental to social interaction between kids...

She continued and said:

I felt this need to actually talk to other people while I was doing my map. I talked with friends or anybody who was around ... I thought that this is not an anti-social learning activity. It is definitely something where you do interact with others and you're looking at what they're doing and they're looking at what you're doing and you're asking them what they think about what you're doing. All the time your comparing the concept mapping that you make with others because everybody's coming from different angles.

This transcript illustrates the misconceptions that Leanne has about the antisocial nature of computers in classrooms. Further research into this issue is justified as the stereotyped image of the isolated person working alone at a keyboard may have a strong influence on

Two final quotations from two women (who have school age children) illustrate the variety of views about how children could use such materials. Mary (aged, 38) stated:

Well I took a copy (of the software) home; my daughter was playing with it too.

My son's now trying to make his own map so they are interested in it.

The children are 7 and 11 years old, respectively.

Val (aged, 35) had a very different view and stated:

I wouldn't conceive that you would get many children from middle primary (children under 10 years of age) and below who have got the typing skills, the computer technology, literacy to be able to do this.

Her children are 9 and 12 years old. Thus even though Val had successfully used the cognitive tools she showed that she had doubts about the ability of younger children to use the technology. Unfortunately such attitudes are prevalent and can limit much of what occurs with computers in classrooms.

Analysis of data from the concept maps about rainforest destruction.
The purpose of this part of the study was to analyse the concept maps that the preservice teachers constructed after they had accessed all of the information about rainforest destruction.

When the preservice teachers began to use the tool to construct their concept map about rainforests they were advised to construct it the way that they normally would. They were not expected to produce a perfect map but were advised to concentrate on producing one that would show what they understood about the information provided.

How the data were organised.
The method for organising and analysing the data is similar to that reported by Beyerbach (1988). In her study, she created an alphabetical list of the concepts created by her subjects and then tabulated the frequency of these concepts in the maps composed by her subjects.
During this study all concepts listed satisfied the original definition of a concept (see Chapter 2). First concepts displayed on the concept maps were noted, then those written in attached notes were added. An alphabetical list was then compiled. The original list consisted of 80 concepts but 5 were grouped with others because they were synonyms and one was eliminated as it was considered trivial. This left a total of 73 concepts in the list. To check the validity of this approach a sample of 40 maps was given to a colleague who was qualified in science education. He made an independent list of concepts from these 40 maps (15 with notes and 25 without notes) and his list was then compared to that of the researcher. His list contained 70 concepts compared to 63 in the researcher's list. When the researcher and the colleague discussed synonyms the differences reduced to four concepts: "ecosystem" and "environment", "debt" and "poverty". They agreed that these concepts should remain separated. The final list of 74 concepts was referred to two independent researchers who were experienced in environmental education. They felt that the concepts in the list were relevant to the topic of disappearing rainforests and concepts were appropriate.

The data were recorded on spreadsheet and concepts written on to the main map were distinguished from concepts entered in the notes. Totals were obtained for individual maps and frequencies for individual concepts obtained.

The concepts displayed on the maps
Table 7.18: Summary statistics for the concepts displayed on the maps and notes

<table>
<thead>
<tr>
<th></th>
<th>Concepts on Maps</th>
<th>Concepts in notes</th>
<th>All concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>11.2</td>
<td>5.5</td>
<td>13.7</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>11</td>
<td>5.5</td>
<td>14</td>
</tr>
<tr>
<td><strong>Mode</strong></td>
<td>12</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>3</td>
<td>2.7</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>Variance</strong></td>
<td>9.17</td>
<td>7.4</td>
<td>10.4</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>14</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>20</td>
<td>11</td>
<td>21</td>
</tr>
</tbody>
</table>

The mean was 11 and the standard deviation 3. The range is 14, from a minimum of 6 concepts to a maximum of 20. However the analysis only considers concepts displayed
on the map. When the concepts displayed in the notes are included the distribution in the
right-hand column appears. The mean is now 14 and the standard deviation is still 3, and
the range is similar. The data shows that it is also important to consider the attached
notes when analysing concept maps created by this tool. Thirty four preservice teachers
attached notes to concepts and/or links. Table 7.18 shows that the mean of concepts that
were written in these notes was 5 (S.D. 2.7). The large range may indicate that there
were large differences in how and when the tool was used.

Since learners may use the concept mapping tool in a variety of ways to structure their
knowledge, any assessment procedure will need to consider this. Certainly any simple
system of counting concepts and links drawn on a map is likely to be inappropriate.

*Where the preservice teachers wrote their concepts*

The number of preservice teachers who attached notes to their concepts was thirty-four
(42.5%), but it is likely that the notes would have been more extensive and more
preservice teachers would have attached notes if they had the opportunity to spend more
time constructing the map. However, the aim of this part of the study was to find out
how the preservice teachers began to construct their concept maps with the tool rather
than to attempt to produce perfect maps.

Table 7.19 displays the frequency and location of the concepts. 17% were written in the
notes and 83% were written on the map.

*Table 7.19: The location and frequency of the concepts listed by the preservice
teachers.*

<table>
<thead>
<tr>
<th>Location of concept</th>
<th>Total frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>on map</td>
<td>914</td>
<td>83</td>
</tr>
<tr>
<td>in notes</td>
<td>181</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>1095</td>
<td>100</td>
</tr>
</tbody>
</table>

This data indicates that, when given free choice, a significant number of the preservice
teachers included concepts in their attached notes. This is to be expected as the concept
mapping tool is used in different ways to pen and paper. Since the data from Table 7.18
shows that the number of attached notes varied from 1 to 11, then it appears that the way
in which the concept mapping tool was used varied a great deal and this finding supports the findings from Study 2.

**Sources of the concepts written in the concept maps and notes**

Table 7.20 displays an alphabetical list of all concepts and their frequencies.

**Table 7.20: An alphabetical list of concepts and their frequencies**

<table>
<thead>
<tr>
<th>Concept name</th>
<th>Feq. map</th>
<th>Freq notes</th>
<th>Total</th>
<th>Attributed source</th>
</tr>
</thead>
<tbody>
<tr>
<td>acid rain</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>alternatives</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>all</td>
</tr>
<tr>
<td>amount of rainforest (%)</td>
<td>7</td>
<td>0</td>
<td>7</td>
<td>graphs, table</td>
</tr>
<tr>
<td>animals</td>
<td>39</td>
<td>6</td>
<td>45</td>
<td>text</td>
</tr>
<tr>
<td>balance</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>text</td>
</tr>
<tr>
<td>biodiversity</td>
<td>39</td>
<td>3</td>
<td>42</td>
<td>glossary, text</td>
</tr>
<tr>
<td>canopy</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>cash crops</td>
<td>13</td>
<td>8</td>
<td>21</td>
<td>text</td>
</tr>
<tr>
<td>cattle grazing</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>text</td>
</tr>
<tr>
<td>classification</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>all</td>
</tr>
<tr>
<td>climatic change</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>conflict of needs</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>conservation/preservation</td>
<td>12</td>
<td>1</td>
<td>13</td>
<td>text</td>
</tr>
<tr>
<td>countries</td>
<td>11</td>
<td>1</td>
<td>12</td>
<td>all</td>
</tr>
<tr>
<td>debt</td>
<td>18</td>
<td>7</td>
<td>25</td>
<td>text</td>
</tr>
<tr>
<td>depletion/destruction</td>
<td>57</td>
<td>3</td>
<td>60</td>
<td>text</td>
</tr>
<tr>
<td>development</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>text</td>
</tr>
<tr>
<td>ecology</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>text</td>
</tr>
<tr>
<td>ecosystem</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>text</td>
</tr>
<tr>
<td>education</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>endangered</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>text</td>
</tr>
<tr>
<td>environment</td>
<td>39</td>
<td>1</td>
<td>40</td>
<td>glossary/text</td>
</tr>
<tr>
<td>erosion</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>exploitation</td>
<td>26</td>
<td>2</td>
<td>28</td>
<td>text</td>
</tr>
<tr>
<td>exports</td>
<td>14</td>
<td>6</td>
<td>20</td>
<td>text</td>
</tr>
<tr>
<td>extinction</td>
<td>13</td>
<td>0</td>
<td>13</td>
<td>all</td>
</tr>
<tr>
<td>Term</td>
<td>Text</td>
<td>Prior Knowledge</td>
<td>All</td>
<td>Glossary/Text</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------</td>
<td>-----------------</td>
<td>-----</td>
<td>---------------</td>
</tr>
<tr>
<td>farming</td>
<td>22</td>
<td>1</td>
<td>23</td>
<td>text</td>
</tr>
<tr>
<td>finance/money</td>
<td>22</td>
<td>4</td>
<td>26</td>
<td>text</td>
</tr>
<tr>
<td>foods</td>
<td>37</td>
<td>2</td>
<td>39</td>
<td>text</td>
</tr>
<tr>
<td>fuel</td>
<td>18</td>
<td>2</td>
<td>20</td>
<td>text</td>
</tr>
<tr>
<td>function</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>future past</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>all</td>
</tr>
<tr>
<td>global</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>greenhouse</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>habitat/home/shelter</td>
<td>47</td>
<td>6</td>
<td>53</td>
<td>glossary/text</td>
</tr>
<tr>
<td>implications</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>all</td>
</tr>
<tr>
<td>importance</td>
<td>8</td>
<td>1</td>
<td>9</td>
<td>all</td>
</tr>
<tr>
<td>industry</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>text</td>
</tr>
<tr>
<td>insects</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>land loss</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>text</td>
</tr>
<tr>
<td>life</td>
<td>9</td>
<td>6</td>
<td>15</td>
<td>text</td>
</tr>
<tr>
<td>location</td>
<td>16</td>
<td>8</td>
<td>24</td>
<td>graph,balloon help</td>
</tr>
<tr>
<td>logging</td>
<td>26</td>
<td>8</td>
<td>34</td>
<td>text</td>
</tr>
<tr>
<td>management</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>medicine</td>
<td>36</td>
<td>3</td>
<td>39</td>
<td>text</td>
</tr>
<tr>
<td>mining</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>non-renewable</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>oxygen</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>ozone</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>people</td>
<td>26</td>
<td>10</td>
<td>36</td>
<td>text</td>
</tr>
<tr>
<td>plantation</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>plants</td>
<td>20</td>
<td>12</td>
<td>32</td>
<td>all</td>
</tr>
<tr>
<td>pollution</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>population</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>poverty</td>
<td>15</td>
<td>6</td>
<td>21</td>
<td>text</td>
</tr>
<tr>
<td>products</td>
<td>23</td>
<td>9</td>
<td>32</td>
<td>text</td>
</tr>
<tr>
<td>rainfall</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>prior knowledge</td>
</tr>
<tr>
<td>rainforest</td>
<td>79</td>
<td>0</td>
<td>79</td>
<td>text</td>
</tr>
<tr>
<td>rare</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>all</td>
</tr>
</tbody>
</table>
reasons 6 0 6 text
regeneration 1 0 1 all
renewable 7 0 7 all
resources 18 13 31 text
species 11 5 16 text
staple food 14 4 18 glossary, text
sustainable 1 0 1 all
third world 33 7 40 text
timber 11 10 21 text
time/rates of destruction 13 6 19 graphs, table
types 3 0 3 prior
uses 5 0 5 all
value 2 0 2 all
vulnerable 9 4 13 all
western world 8 0 8 all

The final third column lists attributed sources of the concepts listed. The procedure described below was adopted when creating this column. It is acknowledged that the procedure is crude and can only be used as a general guide. Concepts that only matched specific words in the text (included the text in the questions), glossary, table or graphs were attributed to that source. Concepts that matched specific words found in the text, table, and graphs were attributed to any of these sources and labelled as "all". Concepts that were not related to any of the sources provided were attributed to prior knowledge.

Table 7.21 synthesises this information into four sources: text and glossary, graphs and table, a combination of the previous two sources and previous knowledge.

Table 7.21: A synthesis of attributed sources of information used by preservice teachers when they constructed their concept maps

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>The text (questions) and glossary</td>
<td>80%</td>
</tr>
<tr>
<td>The graphs and table</td>
<td>5%</td>
</tr>
<tr>
<td>A combination of any of the above three sources</td>
<td>12%</td>
</tr>
<tr>
<td>Previous knowledge about the subject matter</td>
<td>3%</td>
</tr>
</tbody>
</table>
This crude analysis serves to demonstrate that while the text was an important source of information when preservice teachers constructed their concept maps, it was rarely used as the only source of information.

Summary

The investigation of preservice teacher use of the redesigned concept mapping tools further demonstrated that the instructional strategies identified by Gunstone and White (1992); Holley and Dansereau (1984) and Cambourne (1988) could be used to introduced learners to the process of concept mapping and to the supporting cognitive tools. The process of concept map construction was complex and forced the preservice teachers into a cycle of construction of knowledge structures, appraisal of these structures (usually with peers) and further modification. However, the tool was easy to use and preservice teachers could easily modify their concept maps. Hence, the tool enabled them to focus on the concepts and ideas they were constructing rather than on the mechanics of involved in drawing or modifying their maps.

The majority of preservice teachers interviewed employed similar construction methods. Initially they used the concept tool to create their concept names; then they used the other tools to modify and spatially arrange the concept names into a meaningful pattern. The interview data also showed that further investigation of the relationship between preferred learning style and the way in which learners use the concept mapping tool to construct their maps might be justified as a relationship was observed between preferred learning style and the method of use of preservice teachers to construct their concept map. However, with such a small sample other factors need to be considered: it may have been more convenient to keep using the concept tool to generate concepts rather than learning to use other tools.

Analysis of the maps constructed by the interviewees revealed that the quality of the map produced did not relate to the construction process employed. As the tool could be used in different ways, differences in construction methods reflected differences in the way learners prefer to construct their knowledge. Further research may clarify whether differences in the way learners construct concept maps might relate to preferred learning styles. It is likely that learning styles do not affect outcomes in isolation, as the different
methods of concept map construction may also be a consequence of learner use of a flexible concept mapping tool that simply allows them to use different map construction methods.

The cognitive tools that assisted learners to analyse information in text, tables and graphs were found to be easy to use and helped preservice teachers by: reducing cognitive load associated with the sorting and comparing of numbers in columns; and by providing additional information which assisted in information analysis and encoding, such as the location of the counties mentioned in the text, graphs and table. Some preferences for specific tools were noted (for example some preservice teachers preferred to consult the table rather than the graphs) but no pattern that related to preferred learning style was observed.

When students constructed their concept map about rainforest destruction, preferences did emerge. The text and glossary were the main sources of information used, but in most cases this was supported with information from the graphs or the table. Again the patterns of use were not related to preferred learning style.

The concepts that appeared on the maps came from the text and the glossary, but the supporting information found in the notes and the interview responses suggest that the other information sources were used as supplements. For example, several preservice teachers interviewed preferred to supplement the information obtained from text with another source such as a graph or a table because they could add specific facts to their concept notes. Some of the mature age preservice teachers commented that the balloon help alerted them to the fact that several countries would have virtually no rainforest left by the time their children were adults and they felt that it was important to emphasise this issue when they constructed their concept map. Thus the various cognitive tools influenced the content and the overall themes contained in the concept maps. In the case of the graphs and table the influence of the tools was more subtle as revealed during interviews.

By way of comparison the interpretation of the tracking data gathered was problematic and the data could not be used to provide insights about the way in which the tools were used without triangulation from other sources. The data did provide information that
could be used to verify information from interviews and could be used to generate additional interview questions to identify aspects of learner use of the software that could be investigated further by other means. The tracking program may have indirectly assisted in motivating preservice teachers to stay on task as all were aware that the tracking program was operating every time they logged on to the software.

The tracking data were also used with the interview transcripts, survey information and the analysis of the concept maps to describe how the preservice teachers accessed information within the rainforest software. First, it was found that the factors of positive attitude to computers, male gender, a younger age, and preferred learning style were not predictors of the frequency and time preservice teachers spent accessing specific information screens. Second, while it was found that preservice teachers initially focused on the information in the text and the glossary (as this information provided a context for the information presented as a table or graphs) later they accessed some of the additional information to supplemented the text and add meaning to the context. When they accessed the screens containing the graphs and table, they used the cognitive tools and the resulting interviews suggested that these tools helped them to process specific information that was personally relevant. Thus the cognitive tools played an important role in subtly focusing learner attention toward information that supported the theme of rainforest destruction.
Chapter 8: Discussion and Conclusion

As discussed in Chapter 1, learners who successfully interpret graphs, text and tables link the various types of information presented to their semantic memory and they construct meaning by relating the features of the graphs and tables to the context described by supporting text (see Figure 1.1). Throughout, this process the prior knowledge of the learner continuously interacts with the interpretation process.

Study 1 showed that the process of interpreting graphs, tables and related text is complex and creates a high cognitive load for the learner. The cognitive tools designed and evaluated during Studies 1 and 2 provided learners with support that may have reduced the cognitive load associated with processing information from the different sources of information. This chapter is organised into a discussion section and a conclusion that relates the findings from the studies, the literature review and research methods employed. It concludes the study by discussing issues that need further investigation and makes suggestions for future studies. Also, it discusses the use of cognitive tools to support education and learning.

The following section is organised around three major issues that relate to the research questions. These issues are: learner interpretation of graphs and tables; introducing learners to cognitive tools; and the impact of the cognitive tools upon the learners.

Learner interpretation of graphs and tables

Question 1. What factors affect the ability of various groups of preservice teachers to interpret a set of graphs and tables?

Two approaches were taken to this question. The first approach was a quantitative approach that formulated and tested hypotheses. The second used a qualitative approach that relied upon interview data.

The quantitative data indicated that there were significant differences between the ability of preservice science teachers (science graduates) and preservice primary teachers to interpret the graphs and tables contained in the test. This difference could be expected
because the science graduates had greater experience with the context and the skills involved and would have a far greater background knowledge to draw upon.

The absence of difference in scores between Year 1 and Year 3 preservice teachers suggests that two more years of tertiary education had not changed the ability of the Year 3 preservice teachers to interpret graphs and tables. Their scores also indicate that the skills of interpreting graphs and tables are not highly developed in many preservice primary school teachers and more emphasis needs to be placed upon this skill. While similar results may be obtained at other institutions, further studies with larger samples are needed before any wider generalisations can be made.

Regression analysis of the scores obtained by preservice teacher subjects enrolled in Year 1 on the graphing and tables test (dependent variable) were not related to any of the independent variables of gender, age, previous scores in english and science tests, previous experience with computers, and learning style. However, Higher School Certificate Maths scores were found to be a significant factor and 20% of the observed variation in test scores could be attributed to 2 Unit Mathematics scores. This finding is consistent with those of previous studies which also showed that there was a relationship between learner experience in mathematics and ability to interpret graphs (Janvier, 1978; Preece, 1985). Further research is needed to identify the specific mathematical knowledge and skills (beyond basic familiarity) that may help preservice teachers to improve their ability to interpret graphs and tables.

From 1996 all preservice teachers in New South Wales were required to have studied mathematics in senior high school, and this additional experience may have an effect upon their ability to interpret graphs. However, research by Crawford (personal communication, April 17th, 1996) suggests that forcing preservice teachers to study mathematics is unlikely to lead to any improvement. An alternative strategy is for higher education institutions to become pro-active and take more responsibility for developing these skills. There are several ways in which this could be done, but a discussion of these strategies is beyond the scope of this study.

There were limitations with this analysis as it gave no indication about the strategies the preservice teachers used when they were interpreting graphs and tables. The interviews
with preservice teachers allowed the researcher to gain further insights into how they went about interpreting specific information in the form of text, tables and graphs and these will be discussed in association with research questions 2 and 3. Thus, questions 2 and 3 are discussed together.

**Question 2.** What cognitive strategies do preservice teachers employ when they interpret graphs and tables?

**Question 3.** How do the identified cognitive strategies compare with those strategies identified by other researchers?

The findings showed that context always plays an important part in the interpretation of graphs and tables. Commonly used terms such as "element", "velocity", "viscosity" may not be understood by the reader and this makes it difficult if not impossible for the reader to understand the context. The research of Janvier (1978) and Preece (1985) found that understanding the context was essential to the successful interpretation of graphs and that there can be no interpretation without an understanding of "the underlying situational background" (Janvier, 1978, p.3.6).

Often scientific terms have very specific meanings that may differ from common usage and when these key terms are understood learners have a better chance of interpreting graphs and tables. This finding guided the development of the glossary tool that was designed to provide further understanding of important terms used in the text, graphs and tables.

The interview transcripts showed that one of the problems associated with comparing data in tables is cognitive load and this supports the findings of researchers such as Sweller (1988, 1994), Sweller and Chandler (1991, 1994), and Winn (1987). These researchers make specific suggestions about how to organise tables so that the data is arranged in logical and meaningful "chunks" (Yates and Moursund, 1989) that reduce cognitive load. Hence the reader can avoid the problem associated with re-sorting values "in their head". This finding guided the development of the cognitive sorting tool which allowed learners to click on a column heading in order to sort values presented in a table. Thus, some of the cognitive load associated with sorting values was transferred from the learner to the computer.
When the preservice teachers were required to examine and interpret graphs they divided their attention among local and global features. Again these findings support those of Sweller (1988, 1994), Sweller and Chandler (1991, 1994), Janvier (1978) and Preece (1978). Chandler and Sweller (1991) suggested that if examples are reformatted to avoid split attention then cognitive load is reduced, and this makes the task of mental integration easier. This may explain why some of the preservice teachers failed to integrate all of the information. Since mental integration is likely to be cognitively taxing, it is important to save learners from unnecessary mental activity as they process new information. However, where mental integration is necessary, conventional instruction may be better replaced by integrated instructional formats such as those used in this study. The cognitive tools developed to support the interpretation of graphs and tables were an attempt to meet these needs. For example, the balloon help in the form of text and maps only appeared when the cursor was located over a particular value or country. Thus, the learner could control when the information appeared and only had to pay attention to this support when they required it.

Furthermore, the strategies observed and the interview transcripts support the model of processes involved in the interpretation of graphs presented in Figure 2.2 (Janvier, 1978). Such strategies involved reading and interpreting numbers, text and charts, especially key words and terms; labels on axes; rises and falls, and changes of slope on graphs. When a learner is first given a graph to interpret, (s)he starts with either the situation (the context described by the associated text) or the graph. As attention is focused on the graph, its features become meaningful and provide the learner with greater understanding of the original situation presented in the text. Gradually the original situation is referred to less and less and becomes integrated with the graph which becomes the principal conveyer of meaning. Janvier studied the coordination between the situation (text) and the graph and found that the coordination between the two modes of information presented required learners to simplify and memorise one or both. Pure visual simplification appeared to be insufficient and "verbal" summaries spelled out during the checking of a hypothesis appeared to literally replace the graph, but it was also necessary for various global features such as rises and falls, and local features such as
specific labels on axes to be handled in order for the interpretation process to be successful.

During the study some of the preservice teachers misinterpreted the graphs because they did not recognise that a relationship existed between a global feature (eg. a rise or fall or change in slope) to a specific local feature (eg. a specific value or label on an axis). This may have occurred because they were experiencing cognitive load associated with split attention (Sweller and Chandler, 1994). This appeared to happen when they were unsure about which part of the graph they should pay attention to. However, once their attention was directed to the relevant local or global feature most preservice teachers could choose the correct answer. One explanation is that context-specific support (such as balloon help) may help to reduce cognitive load by directing learner attention to contextually relevant features of the information. This situation is likely to be context specific as more complex interactions occur when the text is complex and learners have to interpret text and graphs.

Other common errors such as misreading labels and numbers on axes, and the failure to comprehend legends, may also be associated with cognitive load but further research is needed to clarify this aspect of the study.

Whilst it is not possible to make generalisations from one person, the strategies employed by the best science graduate indicated that she spent less time than the other students in dividing her attention between the different forms of information. She spent longer reading questions but did not have to refer back to them. Her comments showed that she had a very good understanding of the context of each question (which she comprehended from the associated text) and this helped her to quickly identify which parts of the information were relevant. It appears that she had the background knowledge and skills needed to quickly assimilate the information presented and to analyse it in such a way that she reduced the cognitive load associated with split attention (Chandler and Sweller, 1991). This aspect of the study could be followed up in future studies.

As stated previously, the findings from Study 1 guided the development of the cognitive tools that supported learner interpretation of graphs and tables. Graphs and tables were presented in a real life context that included supporting text as this is the way that we
commonly encounter graphs and tables (Janvier, 1978; Preece, 1985). Rather than develop one specific tool, it was decided to develop a suite of cognitive tools that could be used in a more realistic situation where text, graphs and tables were used together to present information. The cognitive tools developed were designed to serve two broad purposes. First, tools were developed to assist learners analyse information presented in text, graphs and tables, and second a tool was developed to assist learners synthesise information presented in text, graphs and tables.

**Introducing learners to cognitive tools**

This section focuses upon how we can introduce learners to cognitive tools that function as mindtools (Jonassen, 1996) and relates the findings to a theoretical model of learning. Thus the discussion focuses upon research question 4.

**Question 4.** Could the instructional strategies identified by researchers in related fields be applied to effectively introduce learners to the concept mapping tool?

While learners have found the concept mapping cognitive tool easy to use, the employment of concept mapping to synthesise information is a process that is developed over time and a basic understanding of the procedure involved does not guarantee that learners will produce concept maps that contain powerful, integrated networks. Time is needed to develop the skills required, to generate and interpret concepts, link and notes. Hence, the separate use of the concept mapping tool prior to its employment with the rainforest destruction data probably made it a more effective tool.

The concept mapping tool was used over five weeks. During this time preservice teachers received four formal lecture/demonstrations and five one-hour tutorials. The computing laboratory was also available for further use for six hours each week. Several factors appear to have contributed to the effective introduction of the concept mapping tool and these may be understood in relation to the major features of Cambourne's model of learning (1988, 1995) as discussed in Chapter 2. These features are immersion, demonstration, expectation, responsibility, employment, approximation and response. These are discussed and related to the research question.
**Immersion**

The term immersion is used to describe the exposure to the process of concept mapping. This exposure should be "whole, usually meaningful and in a context which makes sense or from which sense can be construed" (Cambourne, 1985, p.34). It follows that the process of concept mapping should be presented as a meaningful whole rather than as a sum of a number of isolated entities. Also the process of concept mapping needs to be seen as part of the whole process of information construction about a particular topic rather than as an adjunct.

During this study concept mapping was employed as a strategy to encourage learners to display and link information. The process of concept map construction should encourage learners to process information and present it as a meaningful spatial map. This strategy may encourage learners to become immersed in the total context rather than in discrete parts of the whole.

**Demonstration**

Cambourne described two forms of demonstration: actions (eg. demonstration of how to construct concept maps) and artefacts (eg. examples of good concept maps) and he believed that "demonstrations are the raw material of nearly all learning, not only in language" (p.34). Cambourne claimed that learning only occurs when engagement occurs and this happens when the following criteria are met:

1. the potential learner sees the demonstration as achievable and themselves as being able to do it;
2. the demonstration witnessed will somehow serve some future purpose in their lives;
3. when they attempt the demonstration there will not be any unpleasant consequences.

There is a parallel between Cambourne's criteria and the suggestions made by White and Gunstone (1992) about how to introduce concept maps to learners. During this study the demonstration process appeared to have a positive effect in allaying initial fears concerned with the use of the software and the process of concept mapping. In particular, the
employment of a computer projector in a mass lecture theatre and in tutorials allowed the researcher to employ a teaching process where the researcher and the audience jointly constructed a demonstration concept map. Also the artefacts (student maps) displayed in follow-up lectures and tutorials served to reinforce the notion that the learners were capable of using the software and employing the skills required.

**Expectation**

"Expectations are subtle and powerful coeroes of behaviour", (Cambourne, 1988, p.35) and can work for or against learning. In the context of this study the learners needed to have an expectation that the concept mapping procedure had application in a variety of contexts that were meaningful to their lives. Therefore the researcher needed to provide examples from a variety of meaningful contexts during a period of direct instruction. The use of the tool as a means of planning instruction is an example of how this was done in this context. The preservice teachers knew that they would be planning instructional units in many of their subjects and that they needed to develop these skills. The concept mapping tool provided them with an opportunity to develop and refine skills that they would use many times in their professional careers.

**Responsibility**

The responsibility for supplying demonstrations and for providing the climate for demonstration lies with the instructor. However, learner responsibility also has two levels: firstly, (s)he is expected to become proficient in the total task; and secondly, (s)he is expected to make the decisions about the most useful aspect with which to engage from the current demonstration. When teaching students to construct concept maps, White and Gunstone (1992) suggested that teachers provide a demonstration of a possible layout the first time. This was done in this study and in subsequent lessons the mass demonstration was replaced by short, varied individual demonstrations that were used to show that there is not a single correct answer to the task. During this study the feedback sessions were of particular importance as it was during these times that the researcher was very careful to demonstrate different approaches to the same task and to emphasise that there can be multiple representations of the same domain of knowledge.
Employment

Learners need time and opportunity to use, employ and practise in a non-artificial way. They need to have time and opportunity to work with others as well as time alone to use what they have been learning. When instructing learners to construct concept maps it is important to recognise that learners will need time to work with peers and to work alone. Researchers such as White and Gunstone (1992) and Harlen (1992) mention the need for this to occur when learners are instructed in the construction of concept maps. The findings from this study support this point as the interview transcripts clearly demonstrate that the time at the computer was often only a fraction of the thinking time that was used.

Approximation and feedback (response)

It is claimed by Cambourne that the willingness to accept approximations "is absolutely essential" (p.38). When he models how "learning to mean" proceeds he claims that the cycle of hypothesise, test, modify hypothesis and successive approximation takes place. Such a cycle occurred during the construction of concept maps as learners needed time to use and re-use a newly developed skill, and to reflect upon the knowledge structures they create. It was found that during this phase of 'use', learners need to receive feedback about their performance, and it was important for the researcher, peers and other colleagues to provide both formal and informal feedback. Some of the interview transcripts mention the need to discuss their work with others and how this aspect of computer use had not occurred to them in the past.

This aspect of the study supports previous research conducted by Roth (1994). His study examined student collaboration during the process of concept map construction and his findings suggested that the processes of discussion and negotiation may be more beneficial to learners than the final product (Roth, 1994). Therefore, another area of investigation may be to further explore the discussion and negotiation processes that occur when learners are arranged in small collaborative groups to construct concept maps.

The approach adopted during this study was also similar to those recommended by White and Gunstone (1992) when they suggested an approach for teaching children to construct concept maps. Their steps also parallel those of Novak and Gowin (1984), Holley and
Dansereau (1984), Jonassen (1996) and Heyrie (1996). It appears that basic instructional procedures are effective, but more basic research is needed before a theoretical understanding of the practice emerges.

During this study Cambourne's model of learning was used to guide the strategies employed when learners were instructed to create concept maps and the findings support this application. In Piagetian terms these principles may be thought of as providing optimal conditions for learner assimilation and accommodation of new information. However, it needs to be recognised that Cambourne's model is not the only model that could have been applied and others could have been used to provide guidance and theoretical support for the study.

Kolb's experiential learning model describes a process through which the four modes of human experience (concrete experience, reflective observation, abstract conceptualisation and active experimentation) are engaged at various levels of complexity to create more complete levels of understanding. His model is based upon four major assumptions:

1. learning is a continual process and not an outcome;
2. learning is grounded in personal experience;
3. learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world;
4. learning involves transactions between the individual and the environment whereby experiences are transformed into knowledge and actions.

Kolb's theory is a holistic theory and it is grounded in the idea that individuals attain higher levels of cognitive complexity through the integration of preferred and less preferred modes of adaptation to their personal circumstances. His model was introduced in Chapter 2 but its operation is summarised in figure 6. This shows a cyclic process in which the learner assimilates experience to create concepts which can be used to generate further experiences and concepts (called accommodating concepts). The process of concept map construction relates to this model in many ways and further research may further elaborate on the application of Kolb's model of learning to the process of concept map construction with cognitive tools.
Cambourne's model uses terms such as transformation, discussion and reflection, and application which together describe in Piagetian terms the processes involved in accommodation or what Kolb's model shows as the accommodation of concepts through experiences. Cambourne believes that all of the processes of transformation, discussion and reflection, and application are interwoven and interact with each other. However, we need to be aware of what these processes are in order to provide optimal conditions for learner accommodation. Transformation is part of this process and occurs when learners take something demonstrated by another and make it part of their own understanding and/or skills. The findings here suggest that this did occur and that the process was enhanced through discussion with others. This supports Cambourne's assertion that "learning, thinking, knowing and understanding are significantly enhanced when one is provided with opportunities for 'talking one's way to meaning,' both with others and with oneself" (p.188). The findings also corroborate the four basic assumptions that support Kolb's model of learning discussed previously. That is, learning is grounded in personal experience that often requires the resolution of conflicts between dialectically opposed modes of adaptation to the world and often this process involves transactions between the individual and the environment (both physical and social) whereby experiences are transformed into knowledge and actions.
Cambourne believes that application involves problem solving and the findings from this study suggest that there is a multi-layered relationship among application, discussion/reflection, and transformation when learners are engaged in the process of concept map construction. Such a process has been discussed in other contexts by a variety of researchers (Bruner, 1966; Wittrock, 1990; Woolfolk, 1990; Vygotsky, 1978; Kolb, 1984). This process of transformation leads to the construction of new understanding or knowledge, or the mastery of new skills. Finally, the new knowledge can be reflected upon and further transformed. Such linguistic interactions are frequently described in association with accommodation (von Glaserfeld, 1995, p.66).

The findings from this study suggest that there are established procedures that we can employ to effectively introduce learners to cognitive support tools that synthesise information but the process needs to be supported by sound educational theory that relates to the context in which the tools are applied. It is not just a matter of designing a suitable tool and then handing it over to the learner to use.

**The impact of cognitive tools upon learners**

This section discusses the findings that relate to the ways learners used the cognitive tools.

**Question 5.** What effect does the concept mapping support tool have upon the way the learners structure their knowledge?

Two approaches were taken to this question. The first approach analysed the maps and identified and discussed the changes. The second approach relied upon interview data.

The findings associated with the analysis of the concept maps and interviews showed that the learners used one of three strategies to construct their concept maps. Some 70% preferred to use a "brainstorm approach" and put all of the concepts on the screen first before rearranging them into a hierarchical, integrated framework that represented their understanding of relationships among the concepts. Then they added links and notes. Another 25% preferred to work in "chunks" and they added a few concepts at a time. These were organised into a meaningful framework that contained links and notes. They then added more "chunks" to this framework. A small number (5%) also used the tool to add concepts, notes and links in a more random fashion. In most cases there was little
difference in the quality of the final map produced, but the appearance may have been
different as the hidden notes feature allowed learners to put notes behind concepts and
link notes. Thus concepts were sometimes embedded in other concepts. It appears that
the concept mapping tool helped learners to visually organise knowledge and this may
have been one of its strengths. Because the tool could be used in a variety of ways, it is
not surprising that learners took advantage of the flexibility. Often at first glance two
concept maps may look very different, but when the underlying structure and content
contained in the notes were examined, a very different perspective emerged. The tool had
just been used in a different way.

The hidden notes were considered a strong feature of the tool as it allowed the preservice
teachers to add another dimension to their maps. Since the notes attached to link labels
and concepts could be hidden, this made more screen space available. This feature
appeared to have two positive effects. First there was more room to create fairly
extensive maps on one screen. This is an advantage as learners can see on screen a map
of all concepts and links (one disadvantage of computer based mapping programs such as
SemNet™ and to some extent Inspiration™ is that they use a great deal of screen space
and the learner only sees a section of his/her map at any one time). While the software
used in this study overcame this problem to some extent, it is not claimed that the current
version is otherwise superior to these applications as they have other strengths. The
second effect was that the hidden notes allowed learners to structure their knowledge in
different ways. For example some created maps that filled the screen with concepts and
then added a small number of notes to their links and concepts. Others created fewer
concepts on screen but produced extensive notes that contained subordinate concepts.
Both approaches are valid as the final outcomes in each case may demonstrate similar
understandings.

The size of the screen is a limitation and it was tempting to create a software application
that could have multiple dimensions. Learners would then be advised of their position
through navigation prompts. However, this adds another layer of complexity and would
place an additional cognitive load on the learner. Only one of the interview transcripts
mentioned limitations associated with screen size and none of the field notes of the
observers commented on this problem. However, it would be an issue if learners were creating very extensive concept maps.

The tool allowed learners to create their maps in a variety of ways and probably this made it easier for learners to use. Some other tools (eg. SemNet™) that were trialled placed restrictions on how learners could create their maps and initially. This appeared to limit the way learners use the tools to structure knowledge. A useful follow-up study would be to compare the ways in which learners used different mapping tools to structure their knowledge as the findings from this study seem to indicate that, initially, tools that can be used in different ways to make the task of concept map creation easier. However, over time learners may adjust to less flexible tools and eventually use these tools efficiently to create concept maps (Jonassen, personal communication, September 6th, 1996).

**Question 6.** Do the cognitive support tools assist learners to analyse information in text, tables and graphs?

The cognitive tools designed to assist learners analyse information in text, graphs and tables were the glossary, the questions, the sorting tool and the balloon help. The data suggests that the cognitive tools did help learners to analyse information presented in text, graphs and tables. The use of the tool appeared to be idiosyncratic and varied with the individual and the context of his/her situation.

The most valuable data associated with preservice teacher use of these features came from the interviews conducted with subjects as they worked through the software for a second time. Prior to the interviews the preservice teachers had used the software to answer questions and to construct a concept map that synthesised the information presented. Thus they came to the interview with previous experience that they could draw upon as they once again worked through the software. The cognitive tools will now be discussed separately and finally a summary will synthesise this section of the discussion.

**The glossary words**

The text contained key words that were in bold red print and the user could link to a glossary when they clicked on such a word. This feature was mentioned by all of the preservice teachers interviewed and most explained that the brighter colour stimulated
their curiosity. Because support was provided at the point of need, this tool can be thought of as a performance support tool as defined by Gery (1991).

The glossary tool avoided the need to look up the meanings of words in a dictionary. Also, as one preservice teacher involved in the study stated it could be used as support "for people with English as the second language." Thus the glossary helped learners to understand key words which then allowed them to understand the context (or as Janvier, 1978 states, "the situation") associated with the graphs and tables. Another use of the glossary was to help learners identify key concepts when they constructed their concept maps and eight interview transcripts mentioned the use of the glossary in this manner. Thus the glossary was used as a support tool to help learners understand key words in the text and in the process of knowledge construction when learners began to construct their concept maps. Further development of this tool could include links to graphics that provided visual illustrations of key terms.

**Table**

The table displayed a set of figures relating to rainforest depletion. The figures in each column could be sorted in ascending order when the user clicked on the words in bold red in the heading. Again all preservice teachers mentioned this feature and most realised that it was a tool that helped them to process information. The following quotation supports the contention that the tool served to reduce cognitive load (Sweller, 1994, Sweller and Chandler. 1991):

"It does it in the way that you get, instead of having to mentally visualise it ... sort it in their own heads like right in front of you. It's easier to picture really, to understand."

However, the sorting tool could also be used to test hypotheses and several of the preservice teachers saw this as an additional use of the tool.

**Graphs**

The graphs contained balloon help that was activated when the cursor was located over the names on the axes labelled "countries" and the numbers at the end of the bars in the graphs. The balloon help on the axes labelled "countries" provided a small coloured map that displayed the location of the country in its home continent. The balloon help on the
numbers provided additional explanatory text about the numbers. This form of help is once again, "just in time" or a performance support tool (Gery, 1991).

The balloon help on the axes was considered to be an excellent feature, but it is possible that the balloon help could act in reverse and instead of supplying information at the time of need, it could have diverted the learner's attention from the global features. This could have created additional cognitive load (Sweller, 1994; Chandler and Sweller, 1991). The interview transcripts do not support this interpretation, but further investigation of this aspect of the study is warranted.

Most preservice teachers mentioned that the balloon help for the numbers provided useful explanatory text and the text reinforced what the graph displayed. Others felt that it did more than this because it provided additional information. Therefore the balloon help did help learners to analyse the data presented in the graphs, but one aspect that needs further investigation is any relationships that may exist between the form of help provided and the learner's preferred style of learning.

An unexpected outcome was that many of the preservice teachers admitted that they didn't know where continents and countries displayed in the balloon help were in relation to Australia. This finding needs further investigation with a larger sample as it may be a factor associated with this group of students or it may reflect a more general lack of geographic knowledge.

The questions

The questions were devised to encourage learners to find information from the text and from the graphs and the table. They were supplied on a separate sheet of paper, this avoided the problem of flipping back and forth to the questions while accessing the information.

To answer questions, preservice teachers could rely on memory but most questions required looking at text and the table or graphs. Some preservice teachers preferred the graphs as a primary source of information while others preferred to use the table or text. The reasons for these preferences are not entirely clear, but they may be related to past experience as several interview transcripts revealed that the preferred form of information was usually the one that the learner was "most comfortable with". For example Helen
used the text as her main source of information and explained that, "I used the text because I'm a text ... a word person, I'm a reader ..." but she also used the graphs as a means of verifying the information she obtained from the text.

The primary function of the questions, however, was to encourage learners to process the information provided and to take the task seriously. It may have been easier to position the questions adjacent to the screen which contained the relevant information, but this would have encouraged learners to rely upon one form of information rather than use the other forms available.

The cognitive tools were used by learners to assist them to process information and their effectiveness varied according to idiosyncratic factors associated with the learner preferences and the way in which the tools were presented to the learners. Also the learners realised that the tools could be used in ways that the researcher had not anticipated. This aspect of the study describes a finding that is typical in educational settings: that learners are likely to devise unintended ways of using cognitive tools.

**Question 7.** What evidence is there that these cognitive tools had an impact upon the concepts developed by the learners?

This part of the study examined the ways in which information about rainforest destruction was accessed, what cognitive tools were used and whether this information had an impact upon the concepts developed by the preservice teachers. The interview data indicates that the preservice teachers accessed different forms of information in order to construct their concept maps, but the analysis of the structure and content of their concept maps showed that they did not appear to be related to the forms of information accessed. Further research is needed in order to fully understand this aspect of the study.

The tracking data showed that when the preservice teachers were developing their concept maps associated with rainforest destruction more time was spent using the text and glossary than any other information source. Interviews supported this interpretation of the tracking data and revealed that the glossary was often used as a first source of concepts and then other supporting information was gathered from the text, table and graphs. The graphs and table were accessed for shorter periods of time as often they were used to clarify and verify information or concepts. Those who accessed the table
used the sorting tool to re-examine trends, in particular the "years to end" column. Similarly the "years to end graph" attracted more attention than the other graphs and the balloon help was used by those who accessed this source (13/15). The interview transcripts indicated that the preservice teachers wanted to view the information because it related to events that would happen within the learner's life span.

The tracking data files containing time spent and frequencies of using specific cognitive tools reflect the wide variation that would be expected from a group of adults who were engaged in a task that was not constrained by a minimum or maximum time frame. However, time can be a misleading variable if it is used in isolation. For example, the raw data does not tell us if the preservice teacher who took 50 minutes using the concept mapping tool spent any more time on task than the preservice teacher who took 30 minutes as (s)he may have spent time talking to peers while the other focused entirely on the task at hand. Therefore interview data and general observations are needed to verify the tracking data and to clarify any discrepancies.

Interviews provided insights into why different learners preferred to access different forms of information. These are related to learner preferences for specific forms of information, learner efficiency in processing the information needed, and previous experience with the subject matter. Furthermore, interviews supported the interpretation that some but not all learners have preferences for specific forms of information such as text. However, analysis of the concept maps did not identify any differences in map content or structure that could be related to these preferences. Three possible explanations are discussed below.

First, the concept mapping tool allowed learners to construct knowledge structures that appeared at first glance to be very different, but further analysis of the content in the hidden notes often showed that the structures were similar. Thus the differences in the constructed concept maps were related to the way in which the learners used the concept mapping tool to construct their maps.

Second, while learners took different pathways through the information that they needed for the construction of their concept maps, often the concept maps they developed to represent their understandings were similar. Some of the interviews suggested that the
form(s) of information accessed at a particular time related to the information needed, ease of access, ease of processing of the data required, and/or learner preferences for specific forms of information. The similarities in the maps constructed indicate that the various forms of information presented to learners helped some to develop similar knowledge structures. Furthermore, learners may construct better concept maps when they have access to information that is presented in a variety of forms as this allows them to compare and contrast the different forms of information. Certainly some of the interview transcripts indicated that learners accessed the different forms of information for these purposes.

Third, it is possible that most preservice teachers could have come to the task with a great deal of background knowledge about the topic (e.g. some may have studied the topic in Geography in senior high) and didn't need to use the supporting information. However, only two of the preservice teachers interviewed indicated that they had previously studied the topic.

One factor that may influence the way in which learners access information and construct their concept map is preferred learning style. While the data from this study did not show that the concept maps created by the preservice teachers were related to their preferred learning style, further investigation is warranted as some other researchers (Schreiber and Abegg, 1991; Reiff and Powell, 1992) have reported significant findings in different contexts. However, a recent study reported by (Kessler, 1995) failed to replicate their work when he examined the relationship between cognitive style (as measured by Kolb's instrument) and total concept map score (based upon the criteria of Novak and Gowin (1984). Thus the findings from this study and other recent studies have failed to clarify whether a relationship does exist between the scores learners receive for the concept maps they construct and their cognitive style. This is not surprising given the problems that Shalveson (1993) reported with the methods used to score concept maps. Such problems related primarily to the reliability and validity of the numerical scoring methods adopted by researchers.

During this study interviews were also used to ascertain whether there were any relationships between a learner's learning style and the form of information they preferred to use when they constructed their concept maps. While no relationship was found, it
needs to be kept in mind that the sample interviewed was small and a larger sample may yield different results. At this stage it is prudent to state that during this study no relationship was observed among learning style (as measured by Kolb's inventory), the form of information accessed and the final structure of the concept map was observed, but the issue warrants further study. Also it may be useful to investigate whether preferred learning styles are related to the procedures learners use when they construct concept maps.

**Question 8.** Do the tracking data help researchers in understanding the way in which the tools were used?

The tracking data was collected automatically after the user logged on to the software. This allowed the researcher to collect a large amount of data automatically, but in this case a large volume of reliably collected data does not necessarily equate with easily interpretable information. As previously stated, we cannot be sure that the preservice teacher who took 50 minutes using the concept mapping tool spent any more time on task than the preservice teacher who took 30 minutes. However, when observations and other data sources are used to validate the tracking data, the information becomes useful. For example, the tracking record of events showed short-term access (eg. 40 to 80 seconds) to graphs and tables. Interviews and observation records about such short-term events confirmed that learners were accessing specific data in the graphs and tables that related to the text or their concept map.

Consideration was given to generating maps of learner audit trails (Williams and Dodge, 1993; Misanchuk and Schwier, 1992) but it was felt that the use of multiple data sources such as interviews would be more helpful for the purposes of this study. In future studies maps of audit trails may be used to supplement other sources of data.

**Question 9.** How did the learner access information?

The findings showed that there was no relationship among any of the following independent variables of attitudes to computers score, gender, age, preferred learning style, and the dependent variables of time spent in using the application and the frequency of subject referrals to specific screens of information. As discussed previously, this sort of information is not that useful unless it is supplemented with data from other sources.
Interviews confirmed that the total time preservice teachers spent accessing specific forms of information reflected the relative importance of the information source in assisting learners to construct their concept maps. For example, the text was accessed for longer periods of time than the graphs or tables and this preference for text-based information probably reflects the demands of the knowledge construction task that the learners were engaged in, and preferences associated with their tertiary studies. However, other forms of information were accessed when needed. The interviews indicate that this usually occurred when specific facts were needed to illustrate a concept or to explain a link. There were exceptions though, and the transcript of Loretta, for example, showed that she spent much of her time in reading, sorting and interpreting the table as she felt that it was easier for her to process information that was in this form.

At this stage the findings relating to this research question can be discussed. First, learners accessed their primary source of information for longer periods of time and more frequently. Few accessed all other forms of information as they constructed their concept maps; instead they briefly accessed specific forms of information needed to supplement the information contained in the concept map that they were constructing. Second, the form of information accessed to supplement the primary information source appeared to reflect the learner's preferred form of information (as indicated during interviews).

**Conclusion**

For almost two hundred years authors have recognised that enormous amounts of information could be presented in graphs and tables, and in 1801 William Playfair wrote that graphs and tables could represent:

"... as much information may be obtained in five minutes as would require days to imprint on memory, in a lasting manner, by a table of figures" (Playfair, 1801b, p.12).

More recently Weintraub (1967) asserted that graphs and tables have an increasing role in our society and "... often distil a wealth of information into a small amount of space" (p.345).

The notion that we can assimilate the wealth of information displayed in a graph or table "at a glance" and that much information can be "imprinted" on memory can be misleading
as researchers inform us that humans frequently find it difficult to process the multiple forms of complex information contained in graphs and tables (Janvier, 1978; Preece, 1985; Chandler and Sweller, 1991, 1994). It is paradoxical that the strength of information displays presented in the form of graphs and tables can also be their weakness.

During this study, cognitive tools were developed to act as mental devices to support, guide and extend the thinking processes of learners so that they could more easily understand information presented in text, graphs and tables. The tools were external to the learner and computer-based. It is now appropriate to conclude this study with some discussion about some general implications that have emerged.

**Investigating learner interpretation graphs and tables**

The findings from this study support the research findings reported by previous researchers who used similar techniques (Janvier, 1978; Preece, 1985). More extensive research is needed into cognitive load theory (Chandler and Sweller, 1991, 1994) as this is a promising avenue of research that may be related to cognitive tools. In particular, we need to understand how we can reorganise graphical and tabular forms of information so that it is in a form that reduces cognitive load. Furthermore, research techniques that provide a rich source of data such as video recording of learners, and interviews that are combined with computer-based tracking of learner interactions with graphs and tables could be used to help to develop further understanding of the causes of cognitive load.

It may be fruitful to investigate multiple mechanisms for reducing the same source of learner cognitive load as the form of support provided may relate to the learner's cognitive style. Furthermore, it may be productive to further investigate how "mental integration" (Chandler and Sweller, 1991, p.330) may be supported with other mindtools (Jonassen, 1996).

**How to introduce learners to cognitive tools**

The way that we commonly encounter graphs and tables is in association with text and typically this occurs in a newspaper, book or magazine. Therefore we can expect that the context and the prior knowledge of the learner will have an effect on the interpretation of graphs and tables (Janvier, 1978; Preece, 1985). The cognitive tools were developed to
provide support in a learning environment that reflected the context where learners usually encountered text, graphs and tables.

It was important that a more complex cognitive tool like the concept mapping tool was introduced first so that learners were proficient in its use before they used it in a different context. The methods adopted to introduce learners to the concept mapping tools were well established by other researchers and this study showed these procedures were applicable in a different context.

To introduce each tool separately over a period of weeks would have been time consuming and it is uncertain if this would have been of any benefit. However, a future study could compare how different introductory procedures affect learner use of simple cognitive tools.

The supporting theory adopted was based upon Cambourne's model of learning (1988, 1995) and the key ideas associated with his theory appear to support the instructional sequence chosen. Two key points that emerged. First, the concept mapping tool was employed in a context that was meaningful to the learners and this promoted "engagement" (Cambourne, 1988). Second, the concept map produced was relevant to an important task that occurred later in the year (a knowledge map related to an instructional unit). This is an important point as learners are more likely to be focused on a task if they believe that the task is relevant to their lives. An important piece of theoretical research would be to attempt to apply Cambourne's or other suitable models such as Kolb's to other visual and mindtools (Hyerle, 1996; Jonassen, 1996).

**Learner use of cognitive tools**

During this study the cognitive tools were used by learners to analyse and to synthesise information. The cognitive tools used for analysis were designed to be activated at the moment of need and to reduce cognitive load associated with the processing of information that was presented in a variety of forms. It may have been important for the learner to be able to de-activate these tools as Chandler and Sweller (1991) report that "the isolation and elimination of redundant sources of information are preferable" (p. 330), particularly where mental integrations of information occur. It would also be useful to compare the effects of cognitive tools (such as balloon help) under varying
conditions of availability such as: unavailable; permanently available; available when activated by the learner.

The concept mapping tool was a knowledge construction tool that synthesised (integrated) the various forms of information in a knowledge map. It is a tool that is compatible with a constructivist approach to learning (Jonassen, 1996; Hyerle, 1996). This tool, and others like it, provide researchers with concrete examples of computer-based constructivist learning environments. The ease of use of the tool and the flexible ways in which it can be used creates a research environment that may be suitable for exploring the effects that factors such as cognitive styles, learning modalities, cultural differences, language differences, communication styles, and multiple intelligences may have upon the knowledge structures that learners create.

Finally, concept mapping engages learners in higher order thinking skills such as critical thinking, creative thinking and complex thinking (Jonassen, 1996). Further research is needed to understand how these higher order thinking skills interact with each other when learners are actively engaged in the process of concept map construction. The findings may help researchers to develop more effective instructional processes and cognitive tools.

**Learner construction of knowledge with cognitive tools**

When learners construct a concept map they are required to identify important concepts in the content domain, spatially arrange them, link them and attach explanatory notes. The order in which these processes occur varies according to learner characteristics and limitations associated with the concept mapping tool being used.

Jonassen (1996) describes in more detail a similar sequence, but adds that while linking is going on, new concepts are being added to the map as these explain existing concepts. These concepts are linked and then additional concepts are added to explain them. "This process of augmentation continues until the builder feels that the domain is explained well enough" (p.98). He contends that "this process mirrors to some degree the natural pattern of knowledge acquisition" (p.98). This idea of accretion of concepts was mentioned by Norman in 1976, but now we have the opportunity to use computers and video technology to closely monitor the process of concept map construction. This
information may help us to develop a much deeper understanding of the mental processes involved.

During this study learners appeared to use one of three strategies to construct their concept maps. Some preferred to put all of the concepts on the screen before rearranging them into a hierarchical, integrated framework before they added links and notes. Another group preferred to work in "chunks" and they added a few concepts at a time. A small number added concepts, notes and links in a more or less random fashion. However, there was little difference in the quality of the final map produced.

Further investigation of the process of knowledge construction with concept mapping tools is justified as different patterns of knowledge acquisition may be related to the specific characteristics of the learners. During this study, no such evidence was observed and a reason may be that the learners were not forced to focus upon a narrow domain of knowledge. A study that focused upon a very narrow domain of knowledge acquisition (eg. electromagnetic induction) may produce different results. Finally it needs to be acknowledged that the learners may have used the concept mapping tool in different ways because it allowed them to employ a variety of methods of knowledge construction.

The data on collaboration during the process of concept map construction suggests that the processes of discussion and negotiation may be more beneficial to learners than the final product (Roth, 1994). Therefore, another area of investigation is to further explore the processes that occur when learners are arranged in small collaborative groups to construct concept maps. This investigation could be further extended to cross-cultural collaboration via the internet.

This study examined learner use of cognitive tools in a narrow context and the discussion that follows expands upon this context. While a certain amount of caution needs to be exercised when extending the findings to other contexts, it still is important to explore future applications of the research.

Currently there are many computer-based visual tools available and all have their strengths and weakness. As computer technology improves it will become even easier for a learner to add more graphics and colour images to concept maps and further development of these tools will lead to seamless links to the internet where learners in
different locations may collaborate to build shared knowledge structures. Indeed at this point in time one could conceive of the internet as an enormous, dynamic knowledge structure that represents some of the personal and shared knowledge from over 60 million learners! Such a map is too big to be useful until learners become successful navigators and explorers, or "infotectives" (McKenzie, 1996). This structure will then become a valuable learning tool, providing learners have the tools to construct meaning from the information they find. Once again it may be the collaboration procedures that learners use in building their knowledge structures that prove to be more important than the product.

However, a word of caution needs to be voiced as the next generation of visual tools (or mindtools) need to be carefully designed and then carefully introduced to learners. Hedberg (1989a) asserts that the introduction of technology in education has a history of broken promises and poor performance. As a result many teachers and administrators have become wary of visionaries bearing computer-based gifts (Sewell, 1990). This lack of acceptance and adoption of technology in schools can be traced back to the way that each invention is presented and marketed (Hedberg, 1989a). Too often the invention is presented as a solution to many of the problems associated with education and each new design feature is touted as a time saving device that teachers and administrators need. When the invention fails to live up to these promises and is not widely adopted, it is often abandoned and its inventors and supporters roundly criticised. A closer look at the invention may reveal that it did not fail but that the criteria used to evaluate its success were too narrow or inappropriate. For example the time scale used may be too short. It may be more appropriate to judge the invention by the attitudes and perseverance of those who use it as a tool than by the technology itself.

Hedberg (1989a) suggested that this problem of lack of acceptance occurs because too often the hardware of technology is viewed in isolation from the context in which it is employed. Visual tools that assist learners to construct knowledge are an example of a computer based tool that can be used in a variety of meaningful contexts. Furthermore, most are easy to use so the mental effort required to learn to use the software is low. Therefore, one is justified in displaying cautious optimism about the future adoption of these tools. However, before adoption each tool needs to be evaluated and Jonassen
(1996) has suggested how such tools should be evaluated. The criteria that are discussed below are mainly based on his suggestions.

They should be affordable (Jonassen suggests that the costs should not exceed US $100) and should be easy to learn. Generally typical learners should be capable of learning how to use the application within an hour. The screen display should directly represent structural knowledge in a way that is aesthetically appealing to learners, otherwise there is little value over pen and paper methods. Finally learners should enjoy using the application.

**Engagement of higher order thinking skills**

Visual tools when effectively used engage learners in higher order thinking skills (Hyerle, 1996). Jonassen (1996) has classified these thinking skills into groups which he calls critical, creative and complex thinking skills. When learners are constructing concept maps they employ critical thinking to identify, evaluate, analyse and connect information. Creative thinking is needed when learners synthesise or elaborate on information that relate to concepts and links. Jonassen (1996) suggests that hypothesising may also be involved. Complex thinking is engaged when learners develop the layout of their maps and form their links. Such thinking involves a variety of evaluating, analysing and connecting skills.

When instructors introduce learners to visual tools such as the concept mapping tool employed in this study, they need to be aware that the learners are engaged in a complex task that is mentally demanding. Therefore, the process needs to be supported by strategies that assist learners to fully engage their mental abilities. One way is to provide opportunities for discussion and feedback from peers and tutors. Another is for the instructor to engage individual learners in a dialogue that allows them to work in a form of cognitive apprenticeship. However, it is time consuming. Finally, instructors need to provide learners with plenty of time to engage in the process. If there is an expectation by the instructor that the initial product should be of high quality, then disappointment is a likely outcome (White and Gunstone, 1992). However, if the process is valued and the focus is upon higher order thinking, then over time the outcome is likely to be pleasing.
Cognitive tools that provide support at the moment of need

The other cognitive tools developed for this study were forms of "just in time" support (Gery, 1991) and helped learners to process information. They were context-specific, simple to use and required little, or no instruction. Because they were unobtrusive and did not distract learner attention from the main task, they did not split attention and cause additional cognitive load (Chandler and Sweller, 1991).

The support could easily be in spoken information or visual form but it is important to select a form of support that is appropriate to the context rather than opting for a more complex solution. Indeed, a more complex form of support may prove to be counter productive as it may be a distraction and result in additional cognitive load. As more experience is gained with such tools in a variety of contexts we will learn more about their effects and the way learners use them.

Future learners are likely to have access to "electronic books" that include cognitive support tools. The forms that these tools take will depend on the context and on the understandings that we develop about how learners use cognitive tools. This study is only a small step along this path to understanding.
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Appendices

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Appendix 1: Plate displaying graphs by William Playfair (1801)
Appendix 2: Multiple choice test on Graphs and Tables
Courtesy of The Educational Testing Centre, University of NSW.

*PLEASE SEE PRINT COPY FOR PAGES 289-313*

Test of skills in interpreting graphs and tables

INSTRUCTIONS

Answer all questions. Use a HB pencil or black pen to mark your answers on the sheet provided.

When finished hand in the answer sheet plus the questions.
Appendix 3: Skills grid for multiple choice test on Graphs and Tables

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Skills tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C</td>
<td>comparing two graphs</td>
</tr>
<tr>
<td>2</td>
<td>D</td>
<td>reading a table</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>reading labels on axes</td>
</tr>
<tr>
<td>4</td>
<td>C</td>
<td>reading a table plus concept of a complete chemical reaction</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>interpreting scales and reading axes</td>
</tr>
<tr>
<td>6</td>
<td>D</td>
<td>read values and subtract and add</td>
</tr>
<tr>
<td>7</td>
<td>B</td>
<td>compare two line graphs and read the axes</td>
</tr>
<tr>
<td>8</td>
<td>C</td>
<td>read the axes, understanding concepts of speed and acceleration</td>
</tr>
<tr>
<td>9</td>
<td>D</td>
<td>read and compare values on a bar graph</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
<td>as above</td>
</tr>
<tr>
<td>11</td>
<td>B</td>
<td>read a table</td>
</tr>
<tr>
<td>12</td>
<td>A</td>
<td>read a table</td>
</tr>
<tr>
<td>13</td>
<td>D</td>
<td>read a diagram</td>
</tr>
<tr>
<td>14</td>
<td>B</td>
<td>read a table</td>
</tr>
<tr>
<td>15</td>
<td>D</td>
<td>read a series of graphs and relate to a table</td>
</tr>
<tr>
<td>16</td>
<td>A</td>
<td>read a table, concept of hardness</td>
</tr>
<tr>
<td>17</td>
<td>C</td>
<td>read and compare three graphs</td>
</tr>
<tr>
<td>18</td>
<td>C</td>
<td>read a table and recognise the graph from 4 alternatives</td>
</tr>
<tr>
<td>19</td>
<td>A</td>
<td>find the correct graph and data point from a set of graphs drawn on the same axes</td>
</tr>
<tr>
<td>20</td>
<td>A</td>
<td>compare picture graphs with scales and then recognise the correct graphical representation of this data</td>
</tr>
<tr>
<td>21</td>
<td>C</td>
<td>read the graphs, identify data points and compare values</td>
</tr>
<tr>
<td>22</td>
<td>C</td>
<td>correctly related two different graphs</td>
</tr>
<tr>
<td>23</td>
<td>A</td>
<td>read a complex table</td>
</tr>
<tr>
<td>24</td>
<td>B</td>
<td>read a complex table</td>
</tr>
<tr>
<td>25</td>
<td>A</td>
<td>read a table then recognise the graph that represents this data</td>
</tr>
<tr>
<td>26</td>
<td>C</td>
<td>interpret a data display</td>
</tr>
<tr>
<td>27</td>
<td>A</td>
<td>interpret a pie graph</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>28</td>
<td>C</td>
<td>compare histograms</td>
</tr>
<tr>
<td>29</td>
<td>C</td>
<td>read and relate data from a pie and a line graph</td>
</tr>
<tr>
<td>30</td>
<td>D</td>
<td>read and relate data from two line graphs drawn on the same axes</td>
</tr>
<tr>
<td>31</td>
<td>D</td>
<td>plot data on a graph</td>
</tr>
<tr>
<td>32</td>
<td>D</td>
<td>compare data from two bar graphs</td>
</tr>
<tr>
<td>33</td>
<td>C</td>
<td>read a seismogram and read the axes on a graph displaying three variables</td>
</tr>
<tr>
<td>34</td>
<td>B</td>
<td>read a bar chart and compare values</td>
</tr>
<tr>
<td>35</td>
<td>A</td>
<td>read a bar chart and relate values to a data table</td>
</tr>
<tr>
<td>36</td>
<td>C</td>
<td>match diagrams of raw data with histograms</td>
</tr>
<tr>
<td>37</td>
<td>A</td>
<td>read a table of data and apply the definition of specific heat to solve the problem</td>
</tr>
<tr>
<td>38</td>
<td>A</td>
<td>apply ratio</td>
</tr>
<tr>
<td>39</td>
<td>A</td>
<td>plot a data point on a line graph and read the axes</td>
</tr>
<tr>
<td>40</td>
<td>B</td>
<td>compare three line graphs in order to correctly identify a relationship between two variables</td>
</tr>
</tbody>
</table>
Appendix 4: Attitude to computers questionnaire

Please indicate your response to the questions by placing a tick ✓ in the boxes provided.

<table>
<thead>
<tr>
<th>Computer Anxiety</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I am not scared to use computers.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. Working with a computer would make me very nervous.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. I do not feel threatened when others talk about computers.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. I feel aggressive and hostile toward computers.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5.* It wouldn't bother me at all to take computer courses.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. Computers make me feel uncomfortable.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. I would feel at ease in a computer class.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. I get a sinking feeling when I think of trying to use a computer.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. I would feel comfortable working with a computer.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. Computers make me feel uneasy and confused.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Computer Confidence

<table>
<thead>
<tr>
<th>Computer Confidence</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I'm no good with computers.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. Generally, I would feel OK. about trying a new problem on the computer.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. I don't think I would take an advanced subject in computers.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. I am sure I could do work with computers.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. I'm not the sort of person to do well with computers.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. I am sure I could learn a computer programming language like BASIC.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. I think using a computer would be very hard for me.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8.* I could get good grades in university computer courses.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9.* I do not think I could handle a university computer course.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. I have a lot of self-confidence when it comes to using computers.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

* reworded questions
## ATTITUDE TO COMPUTERS

<table>
<thead>
<tr>
<th>Computer Liking</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I would like working with computers</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2. The challenge of solving problems with computers does not appeal to me.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3. I think working with computers would be enjoyable and stimulating.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4. Figuring out computer problems appeals to me.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. When there is a problem with a computer run that I can't immediately solve, I would stick with it until I have the answer.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6. I don't understand how some people can spend so much time working with computers and seem to enjoy it.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7. Once I start to work with the computer, I would find it hard to stop.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. I will do as little work with computers as possible.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9. If a problem is left unsolved in a computer class, I would continue to think about it afterward.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10. I do not enjoy talking with others about computers.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Appendix 5: Learning style inventory

This inventory is designed to assess your method of learning. As you take the inventory, give a high rank to those words which best characterise the way you learn and a low rank to the words which are least characteristic of your learning style. You may find it hard to choose the words that best describe your learning style because there are no right or wrong answers. Different characteristics described in the inventory are equally good. The aim of the inventory is to describe how you learn, not to evaluate your learning ability.

**Instructions.**

There are nine sets of four words listed below. **Rank order** each set of four words assigning a 4 to the word which best characterises your learning style, a 3 to the word which next best characterises your learning style, a 2 to the next most characteristic word, and a 1 to the word which is least characteristic of you as learner. **Be sure to assign a different rank number to each of the four words in each set.** Do not make ties.

1. ____ discriminating   ____ tentative   ____ involved   ____ practical
2. ____ receptive         ____ relevant    ____ analytical  ____ impartial
3. ____ feeling           ____ watching    ____ thinking   ____ doing
4. ____ accepting         ____ risk-taker  ____ evaluative  ____ aware
5. ____ intuitive          ____ productive ____ logical     ____ questioning
6. ____ abstract           ____ observing  ____ concrete   ____ active
7. ____ present-oriented   ____ reflecting ____ future-oriented ____ pragmatic
8. ____ experience         ____ observation ____ conceptualization ____ experimentation
9. ____ intense           ____ reserved   ____ rational    ____ responsible

For scoring only

<table>
<thead>
<tr>
<th>CE</th>
<th>RO</th>
<th>AC</th>
<th>AE</th>
</tr>
</thead>
<tbody>
<tr>
<td>234578</td>
<td>136789</td>
<td>234589</td>
<td>136789</td>
</tr>
</tbody>
</table>

**Scoring the Learning Style Inventory**

To obtain your score on the four dimensions measured by the inventory, Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualisation (AC), and Active Experimentation (AE), sum each column including only those words whose item number appears under the place for the total score. For example, for CE, total the ranks you have given for the words 2, 3, 4, 5, 7, and 8 in the first column. For RO, total the ranks for words 1, 3, 5, 7, 8, and 9 in the second column and so on for AC and AE. Ignore the non scored words in each column. Transfer the four raw scores to the Learning Style Profile below by placing a mark next to the number you scored on each of the four dimensions. Connect these four marks with straight lines (Kolb, Rubin, and McIntyre, 1974).
Appendix 6: Journal questions used with the prototype

Student Names:

1. Comment on the instruction provided during the first tutorial session. Specifically
   - Did the instruction help you to understand how to use the software?
   - What aspects of the process helped you?
     a. the demonstration by the instructor
     b. the practice session in the computer lab
     c. working with a partner
     d. all of these
     e. others - please specify below
   - Were there any aspects of the instruction that were confusing?

2. Describe any problems you experienced when using the software.

3. Please make any suggestions about how the software could be improved

4. Are there any other comments that you want to make.

Part 2: Specific questions about the support features:

1. Did you use the balloon to assist you to read the axes of the graphs? Yes/ No (if
   your response is Yes go to 2, if no go to 3 below)

2. Describe the features of the balloon help that you found useful.

3. Did you use the sorting tool to help you to read the table? Yes/ No

4. Would you prefer to save your maps to a disc? Yes/ No

5. Did you find the concept mapping tool helped you to summarise the graphs? Yes/
   No

6. Were the on-screen buttons easy to understand? Yes/ No

7. Please add any other relevant comments that you want to make.
Appendix 7: Interview questions used with preservice teachers who used the final version of the concept map

1. Comment on the instruction provided during the first tutorial session. Specifically
   - Did the instruction help you to understand how to use the software?
     a. the demonstration by the instructor
     b. the practice session in the computer lab
     c. others - please specify below

2. Were there any aspects of the instruction that were confusing?

3. Describe any problems you experienced when using the software.

4. Do you have any suggestions about how the software could be improved.

5. Are there any other comments that you want to make?

Appendix 8: Interview questions used with preservice teachers who used the analysis tools with the information about rainforest destruction.

These questions were asked after preservice teachers had used the software for the second time. Not all questions were needed as some of the questions were already discussed when preservice teachers worked through the software.

Comment on the instruction provided during the first tutorial session.

Follow up questions if needed.

1. Comment on the instruction provided during the first tutorial session. Specifically
   a. the demonstration by the instructor
   b. the practice session in the computer lab
   c. others - please specify below

2. Were there any aspects of the instruction that were confusing?

3. Describe any problems you experienced when using the software.

4. Do you have any suggestions about how the software could be improved?

Specific questions about the support features:

1. Did you use the balloon help to assist you to read the axes of the graphs? Please explain.

2. Describe any features of the balloon help that you found useful.

3. Did you use the sorting tool to help you to read the table? Please explain why you did (didn't) use the tool.

4. Did you find the concept mapping tool helped you to summarise the graphs? Please explain why you did (didn't) use the tool.

5. Were the on-screen buttons easy to understand? Please explain your response.

6. Are there any other comments that you want to make?
Appendix 9: Sample interview transcripts
*T1/Interview 8: Sally 17.4.96

Q1

First of all I started off with an idea and I created a box with the idea in it. Then I had a few more ideas that were related to that so I just created a lot of concepts on the page, not necessarily in any particular order. Then I moved them around so that they were in some sort of sequence. By moving them around I think I wanted to change the words so I erased those concepts and put in new ones and put in other ones that were better related to the topic. Then I kind of put links in, but because I kept moving the concept around and links don't move, I kept erasing the links so at the moment my concept map doesn't have links in it. It follows a sequence so it looks more like a flow chart without the arrows.

Q2

Well I'd like to put in more notes about each of the things and I think just refine it a little bit more. Because one side, my topic is comets and meteors and at the moment I've got a huge amount of ideas and concepts about comets but I've got hardly anything about meteors so I'd like to develop that side a little bit more and also improve the links. Work out which way the links go and find what are actually meant by some of the concepts because some of them could go either way so I want to make sure that they're either specifically referring to one thing, to one other concept or whether I want them to actually relate to both. Some things like human exploration of comets. Ok, that could refer to Halley's comet or it could refer to comets in general. So I've got to decide whether I want to concentrate maybe more on Halley's comet and because there's a lot more information about it and we seem to have been fascinated about it. It keeps coming back, so we can do more work on it, or whether I want to talk about other comets as well as a twin topic or whether I want to make it a smaller sort of side issue. So I think I've got to get all those ideas to fit in a concept map.

So, because the concepts keep expanding and it's going out like a tree, I keep changing where my main concept is from the top to the side and back again, so that, yeh, because I just want to have it so that it looks, so that I can follow it with my eyes so that I can see the sequence that I'm talking about. Cause I want what's on the screen to look like what's in my brain. So that's what I'm kind of planning to do.

Q3

And have you spent a lot of time thinking about it outside of the lab?

I've spent a little bit of time especially I went home and I got to look at my books on my bookshelf so I found a really good space atlas and a few other things and I work at the science centre where they've been playing a comet video, a video about the history of Halley's comet so I've been sort of paying attention to that so I'm more conscious of things and in the news, when the new comet's been around. I've been much more conscious of things about comets at the moment and I think sort of specifically looking for information on comets, although not so much on meteors because they're a bit harder to get information (pauses) I think.

Q3

Ok, well the most frustrating thing that I found was being unable to move the links. Because I've moved the concepts around so much well as I said before I've given up putting the links in just at the moment because they get stuck there and sometimes they wont erase themselves either. Yesterday I had a few problems. I forgot to clear the screen before I put my concept map up so I got the other person's concept map underneath mine and then some of the links that she'd had wouldn't erase themselves and I kept clicking erase and it wouldn't work so I ended up having, fortunately I hadn't changed too much of my concept map before I realised that suddenly I had animals and their adaptations under comet and thinking surely I didn't put animals and insects here. So I ended up clearing the screen just to get rid of these annoying few links that wouldn't erase, so I
think that's something just the links that don't move or it's probably just, because you can't do everything in a computer program.

Q-The size?

No, the size of the text is OK, although maybe a few words, not so close to the computer screen you'd have a few problems. It's a fairly font because of being a small page. Yeh, with the text, it's a bit hard to sort of, you type something and I've discovered that you can cut and paste the text within the program but once because I thought, k, I've written this note and I'll cut it and copy it and put it in the memory and then I'll clear the screen to get rid of these annoying links and then I'll put it all back, load the whole thing again and paste it in and it didn't work. It only cuts and pastes while you're in that application that is open at the time. But that's ok.

Q-Was the concept mapping tool easy to use?

Yeh, I think I've had a lot of, quite a lot of experience with computers anyway and I'd like think that I'm quite computer literate so I found it very simple to operate and I think, I saw, I noticed that some other people are having problems. They weren't putting their concept map on the whole page because the menu was there whereas I was just moving the menu to where ever it suited me often so that I could fit my ideas on. In fact yesterday I spent part of my time telling the girls on either side of me how to do things with the concept mapping tool. I found it very simple to use and I didn't think it was a problem. I thought it was very basic. Like they seem to be like a lot of people who are scared of computers and even if it is something simple they want to be reassured that they're doing it right because they're scared that it's a big technological thing and it's going to jump up and bite them.

Q4

Well, having used a computer almost continuously for the three years of being at Uni. I have great difficulty with pen and paper now. I think sometimes it's frustrating because you just want to get things done instantly and it takes a bit of fiddling with the computer but it takes a lot more fiddling with pen and paper because if you draw a concept in the wrong place so you draw, you write words in the concept. If you want to change the words, then you actually have to cross it out or start again or use another piece of paper and you end up with lines going here, there and everywhere and scribble and its a bit of a mess. But sometimes can also have the notes. So if you have notes under every concept then the notes could go halfway down the page and then the next concept doesn't fit unless you close the note box.

It's a very neat way of getting the notes behind the concepts. I really liked that idea so that you could have the information about it and the thing of being double lines when it's got a note behind it because then I can say OK, that's the concept that I've been working on, OK, here's another concept which I haven't done anything on yet which I kind of forgot about. Whereas if you writing with pen and paper and you've got the notes on a separate sheet and you've got the concepts on another one it may get, it's not so easy, it's not so visually clear, straight off.

Q-Any other comments?

Yeh, actually it's a good tool and I think it's worthwhile. I think concept mapping's a great idea because it just gets you, it forces you to put the ideas from your head onto paper or onto a computer screen and I remember doing a lot of it in high school science, the beginning of every topic the teacher would make us write a concept map and I think that's a great tool and I hope you can develop it so that it saves better.

Tape 2/ Interview 12 Leanne 18.4.96

Q1
Right, well I basically sort of just dived in because I had my topic sort of in my mind and I hadn't done anything on paper whatsoever. I walked in there basically with an idea in my head and went to work and sort of exploded this concept map about my topic of communication. It ended up very busy and when I look at it now it was very much me organising my thoughts about communication rather than being something that was going to end up being the final product so I used it as a tool that way. What I produced, the first map that I've printed out, is nothing like what my actual unit's going to be because it was me organising my ideas and experimenting with the tool.

Q-Can you tell me how you actually used the tool? Did you put all the concepts on first?

I put all the concepts on first but still I knew where they were going to link if you know what I mean. Like, my thoughts went in a sort of lineal progression like from one concept to another and what built off that and then I'd go to another concept and build off that and another concept and build off that.

Q-Did you have any difficulties in using the tool?

No, very simple to use I thought and I'm not computer wizzy but I found it very user friendly in that respect. I didn't have any problem whatsoever in using it.

Q-Look at your second map that you'd changed: tell me how you have changed your map.

Well the actual structure of the map. I've gone from having my main concept at the top and working down to having my main concept at the side and sort of having a top half and a bottom half and I found I could organise my concepts better by changing the overall format. I've also changed the names of some of the concepts to what I consider to be more related to the activities and the content when I've tried to explain them. Some of them were a bit far too abstract in linking back, so I sort of like I started off with non-verbal and visual communication and I just ended up with visual messages. What I meant by it hasn't changed a great deal but how I've tried to describe it so it's sort of changed in that respect and I've gotten rid of some of the concepts that were there in the beginning. They were more me organising my thoughts than things that I actually needed that I could actually tie to activities and learning activities in the classroom...so I sort of got rid of some of those that were my sort of thinking space really rather than what I was going to do in the classroom.

Q3

I haven't ever asked you about but just the way that the actual notes print out, there doesn't seem to be any sort of specific order in that or is there or I haven't discovered it yet? Or is it in the order that the links were drawn or whatever? I haven't actually analysed it but I, looking at it quickly I can sort of see now.

Q-So you wanted it to actually print out the concepts and notes in the order you created them?

Right, now for example today I just jumped all over the place. To me it would be handier to know which order, or to be able to give them an order that they print out.

Q- When you save your map it actually saves a copy of your map and notes, but it saves the notes separately as a text file. You then can import this into a word processor and just rearrange in the order you want.

So then you can go and pretty it all up and do all things to it can you?

Q-Yes. How did you change your map?

Well, that I actually did do that myself. I attempted in the first go with the concept mapping tool, to write some notes but as I said I didn't have any resources with me the first time either. What I've done is still use some of what I created first because it still fits...
in with the topic. It has been modified in the later ones, do you know what I mean? Having the notes there has helped me because I knew what I was trying to do at that stage. My initial idea has changed a bit but I have still kept some of it because it was OK to start with.

Q4

No, because I used pen and paper to try and prepare to come in and because I was happy to redesign my concept map. I started from scratch today because it was just too different, the whole layout was just too different, but not all of the concept names were all different. I just felt I was better off to start again. So I did it on pen and paper but what I found was I had to have a piece of paper for this note and then some piece of paper for link notes and pieces of paper for this. If you're actually doing it when you're at the computer you haven't got all these sort of things. When I was just inputting it onto the concept map because I worked on it, I sort of was still riffling through sheets of paper here and there. The tool keeps it nice and neat and you know where everything is and you can go from one to the other and check back and that and it's very simple. If you know what I mean rather than as, it stays organised for you.

Q—Would you have children using this application?

Yeh, I think so um, particularly from, from the, looking at it as a technology that is user friendly. I'm sure there's a lot of kids that can manipulate a mouse and do all those sort of things far better than I can and feel more comfortable with it so for them. I think some kids, you know, that need to develop those skills. Basically there is not a lot of difficult fine motor skills needed so they definitely would be physically capable of using the tool. It gives them a way of recording their thoughts and if they're anything like me you can capture those thoughts, before you forget them. Like if you don't, there's no way for you to capture them, once you can lose them. And so this is one way of recording them particularly if you're introducing like a big topic and want to get their initial responses to it. Then maybe look at where their interest lie or where there's holes or where there's misconceptions. A lot of the time particularly when you're looking at scientific concepts, they might have some really way off ideas on how things fit in together and you can identify those so that then you can address in your teaching. So it might be linked up particularly if you're linking things they might have I can't think of one off the top of my head but I know talking to kids and that sometimes they've got some strange ideas about how things work and then how they're related to each other. So you could identify, you know it would help you in identifying a problems like that so you could teach towards.

Q—Finally is there anything else you'd like to add?

No, I think it's been a good experience for me and it's, it's certainly an effective tool for using to plan a unit because it makes you identify all the concepts that are involved in that unit, it makes you think of how you can teach them, what activities, you know the, what you've asked us to do within the map has made sure that we do that and in actual fact it makes you plan a whole unit.

I'll be very honest, I haven't actually started writing up any of the unit part of it yet but it's not going to be difficult because I've done it all, if you know what I mean. In order to get this concept map working right, you have to go through all those things, what are the outcomes on after, which skills, which processes does this activity address, am I addressing designing and making using technology and um, investigation? Am I doing all the things that the syllabus, do you know what I mean, when I look at what concepts, you say you identify your concepts then you look at how you're going to teach them but then you also got to look at whether the activities that you planned are achieving what the broad syllabus sort of outcomes are as well. So in that respect it's just a shame that I don't think you'd have time to do it with everything you wanted to teach but I think I'll have one really good unit.
T2/Interview 5 Helen 28.5.96

Q-Helen, when you look at the text, you'll notice there's some words that are red that allow you to go to a glossary. Do you think it's valuable embedded in text that sort of material?

Yeh, I do because then rather than just not knowing and going on not knowing or not bothering to get a dictionary and find out exactly what it means at the point of need but you'd need somewhere to explain that you can click on to those words but I think it's a great idea because it's hitting you right when you need it. Go to the understanding straight away.

Q-Originally in the first one, version of this I actually had a little picture that went with it.

A-With the description?

Q-Yes, it was only memory problems that stopped me this time. Think that, is it any value or helpful?

Yeh, a picture illustration always assists with the text I think so it would only add to it, wouldn't take it away.

Q-You might remember this table from before. If you move the cursor to a heading, click on it and you can see now it's sorted from lowest to highest. Do you think that this feature helps you?

Definitely because it stops you from having to do it in your head if the need be. Also it tends to have the figures yourself.

Q-Yes, if you have a look at the annual loss table and click on the heading.

The years to end, these get bigger and they get smaller.

Q-Let's look at graph 2.

-It's scary.

Q-I agree with you on that. Let's have a look at graph one. You'll notice that balloons with information appear. What's your reaction to this feature?

A-I think it's great because it gives you the other side of the argument. You see you've got ten years to go in some countries. Also you can see where the countries are. It helps you to put it in perspective or you know in time and space.

Q-Which is the most valuable the text or the map?

Um, for me, you need both.

Q-Do you know where the countries are?

No, I don't but ... well probably the countries would be more helpful for me cause I don' know where they are and I do understand this.

Q-Lets have a look a graph two.

You can that graph has the same features as before. Are they still equally important?

A-I think they're both equally important.

Q-Let's go to the questions now where it says questions. Think back to when you were actually answering the question, did you rely just on the text for your answers or did you use tables or graphs?
I used the text because I'm a text, I'm a word person, I'm a reader but I backed it up. I always back it up to I check because I don't trust myself. So knowing there was a graph I'd read it come to an answer and then check with the graph.

Q-So but your primary source was a text and the secondary was just a backing up of the other.

Yeh, even though I understand it I could've quickly looked at a graph and probably got the answer. That's, because I'm just text orientated.

Q-Where did you get the information from when you were creating the concept map?

First, what was in my head and then I went back.

Q-Where did you go back to?

Firstly the text because like I said before I'm a text person but then knowing the graphs were there I had a look at the information.

Q- Do you think that this sort of approach is worth pursuing with children down the track?

Definitely cause it will help them to understand the graphs, not be threatened by a lot of text or a graph - they're all related. And I like the idea of doing a concept map at the end cause you can see what you've understood. I've latched onto the concept maps for pre and post instruction I'm learning.

Q-Any other comments you want to make?

No, I think it's useful and very easy to use. Like I've mentioned before, I have problems with actually using computers because I don't often use them unless easy something is easy to use. It's not threatening from that perspective.
Appendix 10: Preservice teacher concept maps revised away from the computer
Appendix 11: Concept mapping software

The following concept mapping tools were found to be available at 26.3.96, but other public domain tools and commercial tools may also exist and Appendix 12 refers to relevant web sites.

<table>
<thead>
<tr>
<th>Software</th>
<th>Version</th>
<th>Platform</th>
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<tbody>
<tr>
<td>Inspiration</td>
<td>4.0</td>
<td>Mac/Windows</td>
</tr>
<tr>
<td>TkstNet/TextVision</td>
<td>1.40</td>
<td>Mac/Windows</td>
</tr>
<tr>
<td>CMap</td>
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<td>Mac</td>
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<td>LifeMap</td>
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<tr>
<td>KennisGraaf</td>
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<td>Structure Activator</td>
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<td>SemNet</td>
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<tr>
<td>MindMapper</td>
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<td>Windows</td>
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<tr>
<td>MindMan</td>
<td>2.0b</td>
<td>Windows</td>
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<tr>
<td>Mind Mapping Tool</td>
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<td>Mac</td>
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<tr>
<td>VisiMap/InfoMap</td>
<td>1.4021</td>
<td>Windows</td>
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<tr>
<td>Flowchart tools eg MacFlow</td>
<td>3.7</td>
<td>Mac</td>
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<tr>
<td>General drawing tools</td>
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<td>Mac and PC</td>
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</tbody>
</table>
Appendix 12: Web sites for concept mapping software

Computer tools for concept or mind mapping can be found at:


CMap 2.0 for Macintosh, 
gopher://oldal.mannlib.cornell.edu:9570/40/misc/CMap_2.0.hqx

Banxia Software (maker of Graphics COPE), http://www.scotnet.co.uk:80/banxia/


CoCo Systems maker of VisiMap and InfoMap (Lite), http://www.coco.co.uk/

Activity Map by Time/system Int, http://www.timesystem.dk/software/index.html

EGLE Magic maker of
MindMapperMMInfo@emagic.marc.cri.nzftp://ftp.std.com/ftp/vendors/emagic/mindmap/mindmap.zip
Appendix 13: Permission documents and other relevant information

I need 10 to 15 volunteers to interview on three occasions. The time for each interview will be approximately 30 minutes. The weeks that I need to conduct the interviews are: this week, the first week after the session break and the second week after the session break. All interviews will be conducted in my office.

I can be available at the following times. Monday from 1.30 to 5.00 PM. Tuesday 3.00 PM to 4.00 PM. Wednesday 9.00 to 11.00 AM, and 1.30 to 5.00 PM. Thursday from 12.30 to 5.00 PM. If you can spare the time please nominate a time that would apply for each interview.

Thanks
Brian

<table>
<thead>
<tr>
<th>Name</th>
<th>time</th>
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General Survey

Student Number: ________________________________

1. Place a tick ✓ in the boxes provided to indicate your gender and age
   Gender
   □ female  □ male
   Age
   □ 18-25  □ 26-30  □ 31-35  □ 36-40  □ 41-45
   □ over 45

2. Place a tick ✓ in the boxes provided to indicate the examination subjects you
   completed in senior high school:
   □ I completed English (Higher School Certificate or its equivalent)
   □ I completed Mathematics (Higher School Certificate or its equivalent)
   □ I completed Science (Higher School Certificate or its equivalent)
   □ I completed Computer Studies (Higher School Certificate or its equivalent)

3. Have you passed a university or TAFE or privately taught subject about computers?
   (eg information technology, programming, word processing)
   Place a tick ✓ in the appropriate box.  □ Yes  □ No
   If you answered, "Yes" please specify: ________________________________

4. Do you have access to a computer where you live?
   Place a tick ✓ in the appropriate box.  □ Yes  □ No

5. Place a tick ✓ in the appropriate boxes to indicate your use of computers
   □ I use a computer where I live
   □ I use a computer at work
   □ I use a computer at university during the teaching session
   □ I do not use a computer for any purposes

6. Place a tick ✓ in the appropriate box to indicate the approximate amount of time
   that you spend using computers
   □ I use a computer each day
   □ I use a computer each week
   □ I use a computer a few times a month
   □ I do not use a computer for any purposes

Continued on next page
7. Place a tick ✓ in the appropriate boxes to indicate how you use computers

- [ ] I use a computer for word processing
- [ ] I use a computer for spreadsheet work
- [ ] I use a computer for database work
- [ ] I use a computer to play games
- [ ] I use a computer for other purposes (please specify) ______________________
- [ ] I do not use a computer for any purposes

<table>
<thead>
<tr>
<th>Question</th>
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</tbody>
</table>

Thank you for completing this questionnaire.

Brian Ferry
Dear Sir,

I am a lecturer in Science Education and a PhD student at this institute. My research centres around the development of a HyperCard-based system that assists students to read and interpret graphs and tables. I have spoken to John Faulkner by phone about the possibility of using some of the test items from the Australian Schools Science Competition to rate the ability of subjects to read and interpret graphs and tables. I would also be interested in using the statistical data that relates to the test items.

He suggested that I approach you for permission to use these items, and subject to your approval, I would come to the unit and photocopy the relevant data.

Naturally, I would forward you a copy of my completed thesis and acknowledge the assistance of the Educational Testing Centre.

Yours sincerely,

Brian Ferry
Lecturer in Education
8th March, 1995
Mr Brian Ferry
Lecturer in Education
Faculty of Education
University of Wollongong
Northfields Ave
Wollongong
NSW 2522

Dear Mr Ferry,

With reference to your letter dated 13.2.95.

The Centre will be able to make the requested information available to you. It is the Centre's policy to assist research in this area. There are however a number of conditions which need to be followed.

Individual students and schools are not to be identified and no comparison is to be made between individual students, schools, educational systems or states.

Proper acknowledgment should be made with each test item. For example, a brief phrase "courtesy of The Educational Testing Centre, UNSW" placed at the end of each item used.

We hope we can be of assistance to you and I look forward to reading your thesis when finished.

Please contact Priscilla Dunstan on 313-7238 or 385-4219 to arrange an appointment.

Your sincerely

Jim Tognolini
Associate Professor and Director
15 February 1995

Mr B. Ferry
Faculty of Education
University of Wollongong

Dear Mr Ferry,

I am pleased to advise that the following Human Research Ethics application has been approved:

- Ethics Number: HE 95/06
- Project Title: Electronic Performance Support Prototype
- Name of Researchers: Mr B. Ferry
- Approval Date: 9 February 1995
- Duration of Clearance: 8 February 1996

This certificate relates to the research protocol submitted in your application of 3 February 1995. It will be necessary to inform the Committee of any changes to the research protocol and seek clearance in such an event.

Please note that experiments of long duration must be reviewed annually by the Committee and it will be necessary for you to apply for renewal of this application if experimentation is to continue beyond one year.

Chairperson
Human Research Ethics Committee
cc. Dean, Faculty of Education
Brian Trial 6,3456
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The card Concept Map was open for 141 seconds
The card Questions was open for 10 seconds
The card Glossary was open for 3 seconds
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The card Text was open for 12 seconds
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The card Text was open for 2 seconds
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