Science and Mathematics Education Centre

Getting the HOTS with what's in the box: Developing higher order thinking skills within a technology-rich learning environment

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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Date: April 2007

ABSTRACT

Educators are divided with regards to the value of computer technology as a learning tool. Some maintain that computers have had little impact on students' learning; others suggest that computers have the potential to enhance learning. Within this second group there are those who believe that computers are having a significant impact, while others believe that their potential is yet to be realised. The purpose of this study was to examine the relationship between students working in a technology-rich environment and their development of higher order, critical and creative, thinking skills.

Staff and students from one school participated in this case study. Data were collected by teachers as part of the normal teaching-learning program, supplemented by classroom observations and teacher interviews. In addition, data pertaining to the technology infrastructure was collated from school databases. The data were used to determine the degree of correlation between factors of the learning environment and the extent to which higher order thinking skills (HOTS) were demonstrated by the students. Collations of the statistically significant, and statistically insignificant, correlations allowed relationships between environmental factors and HOTS to be established.

The results indicate that studying within a technology-rich learning environment improves students' higher order thinking skills, determined by measuring their critical and creative thinking. Factors such as length of time spent in the environment have a positive, non-linear effect on the development of critical thinking skills. These factors have no significant correlation with the development of creative thinking skills.

The interaction of students' computer skills and the classroom environmental factors was shown to be complex. Three-dimensional correlations were performed to derive equations that explain these interactions. Students with better developed computing skills scored higher on critical and creative thinking activities. This was most significant for students with better computer programming skills and the ability to competently manipulate Boolean logic. The most significant factors in developing

higher order thinking skills were the students' levels of computer skills, tempered with their attitudes towards computers and computer classes, and the teacher-student relationships within the technology-rich learning environment.

The research suggests that in order to develop students' higher order thinking skills schools should endeavour to integrate technology across all of the learning areas. This will allow students to apply technology to the attainment of higher levels of cognition within specific contexts. This will need to be paralled by providing students the opportunity to develop appropriate computer skills.

ACKNOWLEDGMENTS

There is an amusing story that dates back to the early 1980s, when ICT was beginning its groundswell in education. A university computer club persuaded the student guild to donate $50 towards the purchase of circular debugging devices (CBDs). Unknown to the guild CBD was a euphemism for pizza, often consumed as an aid to solving programming problems. The link between eating pizza whilst focussing on computer tasks is now well established; the permission from Domino's Pizza International and Domino's Pizza Australia & New Zealand to incorporate their business slogan “I’ve got the hots for what’s in the box with the dots” into the title of this thesis is gratefully acknowledged.

Global communications have made it possible for me to seek the assistance of experts that I have never met, and probably never will, who have generously sent me copies of their publications. In particular I thank Emeritus Professor Philip Adey, King’s College, University of London, for allowing me to use the Scientific Creativity Structure Model that he developed in collaboration with Professor Weiping Hu, Shanxi Teachers University, China.

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LIST OF ACRONYMS

ACCC	Attitude towards Computers and Computer Classes
ASCSC	Australian Schools Computer Skills Competition
cAMP	Cyclic Adenosine Monophosphate
CAQ	Computer Attitude Questionnaire
CAS	Computer Attitude Scale
CCEI	Computer Classroom Environment Inventory
CCTT	Cornell Critical Thinking Test
CD	Compact Disc
CECS	Classroom Environment Catholic Schools
CES	Classroom Environment Scale
CLEI	Computer Learning Environment Inventory
CLES	Constructivist Learning Environment Survey
CoRT	Cognitive Research Trust Thinking Course
CTT	Creative Thinking and Technology
CUCEI	College and University Classroom Environment Inventory
DETYA	Department of Employment, Training and Youth Affairs
DNA	Deoxyribonucleic Acid
EWCTET	Ennis-Weir Critical Thinking Essay Test
GCE	General Certificate of Education
GCEI	Geography Classroom Environment Inventory
GPCLES	General Paper Constructivist Learning Environment Survey
HOTS	Higher Order Thinking Skills
IBM	International Business Machines
ICEQ	Individualised Classroom Environment Questionnaire
ICT	Information and Communications Technology
IQ	Intelligence Quotient
IRT	Item Response Theory
LEI	Learning Environment Inventory
LoTI	Level of Technology Implementation
MCI	My Classroom Inventory
PADI	Peningkatan dan Ashuan Daya Intelek (Program for Instruction in Learning and Thinking Skills)

PDA	Personal Data Assistant
PMI	Plus, Minus, Interesting
PKA	Protein Kinase A
PSCE	Primary School Classroom Environment
QTI	Questionnaire on Teacher Interaction
RNA	Ribonucleic Acid
SAEC	Student Attitude and Efficacy Scale
SES	Socio-Economic Status
SLEI	Science Learning Environment Inventory
SPSS	Statistical Package for the Social Sciences
TOET	Test Operate Test Exit
TOSRA	Test Of Science-Related Attributes
TROFLI	Technology-Rich, Outcomes-Focused Learning Environment Inventory
TTCT	Torrance Tests of Creative Thinking
UAE	United Arab Emirate
WCST	Wisconsin Card Sorting Test
WEBLEI	Web-based Learning Environment Inventory
WGCTA	Watson-Glaser Critical Thinking Appraisal
WIHIC	What Is Happening In this Classroom

CHAPTER 1

INTRODUCTION

1.1 THINKING SKILLS IN THE MODERN CURRICULUM

The closing years of the twentieth century saw the establishment of the Western Australian Curriculum Council. In 1998 the Council published the Curriculum Framework. This document outlines “what all students should know, understand, value and be able to do as a result of the programs they undertake in schools in Western Australia” (Parker, Temby, Albert, Barich, Bosich, Cross, Goff, Keely, Kerr, Madin, Rowe, Treloar & Vardon, 1998, p. 6). The Curriculum Framework consists of an Overarching Statement and eight Learning Area Statements. The Overarching Statement outlines 13 Overarching Learning Outcomes. The Learning Area Statements provide a means of integrating the knowledge, values and skills that are integral to students’ education (McMahon, 1999).

Willis and Kissane (1995) defined outcomes as “performance indicators which [sic] either provide evidence of what has happened with respect to a group of students or define a desired state with respect to that group of students” (p. 1). The requirement to develop metacognitive skills was also noted: “Students should be assisted to reflect on their own learning, thinking about how they learn and the conditions which help them to learn” (Parker, et al., 1998, p. 36). The Curriculum Framework Overarching Learning Outcome number six is shown in Table 1.1 (Themby & Jeffrey, 2005). This particular outcome describes, in broad terms, the thinking skills that students should develop and apply across the eight learning areas.

The phrases *critical thinking*, *creative thinking*, and *lateral thinking* are used liberally within the Curriculum Framework but they are not defined. The problems associated with defining these terms will be discussed. However, at this stage they can be considered higher in order than basic knowledge recall skills.

Table 1.1

Overarching Learning Outcome Number Six

	The Arts	English	Health & Physical Education	LOTE
6. Students visualise consequences, think laterally, recognise opportunity and potential and are prepared to test options.	Exploration and development of arts ideas use many different starting points. Ideas are visualised and interpreted through an active process of lateral thinking.	Through a range of processes and strategies, students develop the ability to be reflective and experimental in their use of language.	Visualisation and predictions about future health lead to the selection of courses of action, which are tested and modified as required.	Contextual clues are used to predict meaning. Individuals' thoughts and ideas are expressed in a context that supports critical thinking, problem solving and decision-making.
	Mathematics	**Science**	**Society & Environment**	**Technology & Enterprise**
	Through appreciating mathematics and working mathematically the attitudes, appreciations and work habits developed support critical and creative thinking. Different conjectures are investigated and alternatives are tested.	Through working scientifically, ideas are explored and lateral thinking is applied as predictions are made and further investigations and actions are proposed.	Through investigation, communication, participation and active citizenship, abilities to reflect on experiences, critically analyse, predict answers and develop strategies are developed.	Through the technology process, problems are identified and ideas and designs are created and initiated. Models or prototypes are made, evaluated and changed.

The development of these higher order thinking skills is a significant goal of our education system. It is not a new goal; it is also evident in the Beazley Report (Beazley, Balfour, Collins, et al., 1984), which resulted in educational reform in the 1980s and 1990s. This report highlighted that one of the basic aims of schooling should be to "Develop analytical and thinking ability, and to foster intellectual depth" (p. 25). The conveyance of knowledge should enhance the development of these analytical and thinking skills rather than to accrue facts.

Prior to this, evidence of the desire to address higher order thinking skills exists in the Committee on Secondary Education (Dettman, 1969), which resulted in the

Western Australian Achievement Certificate and Tertiary Admission Examinations (TAE) in the 1970s and 1980s. This report recommended that education should promote the intellectual growth of students by developing their logical thinking and problem-solving skills. It further states, “Schools should emphasise the understanding and use of information rather than its memorisation.” (p. 68).

1.2 STATEMENT OF THE PROBLEM

When examining the role of eLearning in the curriculum, the Victorian Department of Employment and Training (2002) stated that students in general are unable to conduct effective electronic research. They encounter problems with finding and selecting relevant information, particularly from the Internet, and are disinclined to persist with research. Chapter Two outlines the main qualities displayed by students who are higher-order thinkers. This includes building relationships between elements of a problem and using electronic tools to aid their data analysis (Burkhardt, Monsour, Valdez, Gunn, Dawson, Lemke, Coughlin, Thadani & Martin, 2003, online). It would appear, from the Department of Employment and Training, that students do not have the higher order qualities and/or are not developing these qualities when using Information and Communications Technology (ICT). A study of the use of web-based threaded discussion forums by students, Tay, Hooi and Chee (2000) reported a weak reasoning ability of students. This they ascribed to the school system that does not satisfactorily cultivate their critical thinking skills.

Table 1.2 summarises the arguments related to ICT in the classroom. The claims and counter-claims imply that the role of computers in education, specifically in addressing higher order thinking skills, is far from clear.

Maor and Taylor (1993) indicated that inquiry based learning, introduced in the 1970s, has had little effect on the development of higher order thinking. Their research also showed that there was little data with regards to higher order thinking skills in computerised learning environments. In particular, there is little data related to the effect of teachers’ epistemologies on the development of these thinking skills by students. Pelgrum and Plomp (1993, in Maor & Phillips, 1996, online) stated that the integration of computers with education is still in its infancy after twenty years, largely due to the lack of opportunity. Certainly, this research is now more than ten years old. More recently, Roth and Lawless (2001) again stated that there has been little research on the effect of computerised learning environments.

Table 1.2

Purported Strengths and Weaknesses of ICT Integration in the Classroom

Strength	Weakness
1) ICT allows the integration of concepts across the curriculum. Swain, Greer and van Hover (2001)	1a) Classroom practices must change for computers to be efficiently implemented. Scott (1998), Passig (2001)
	1b) Disjointed learning procedures leads to low-level knowledge transmission. van der Straeten and Biesta (1999).
	1c) Computers are used within a pre-existing framework. Kim and Reeves (2004)
2) Technology improves divergent thinking. Allegra, Chifari and Ottavino (2001)	2) This claim is untested. Allegra, Chifari and Ottavino, (2001)
3) Technology as a cognitive tool permits a focus on higher order thinking. Solomon (1993a), Jonassen (1996)	3) There is little data to support this claim. Maor and Phillips (1996), Passig (2001)
4) Word-processing enhances thinking. Allegra, Chifari and Ottavino (2001)	4) Word-processing is not a mindtool. Jonassen (1996)
5a) Combining computers, drama and Socratic dialogue develops thinking. Coley, Cradler and Engel (1997); Sherry and Jesse (2000)	5a) Many programs follow a linear sequence, which does not enhance learning. Stoney and Oliver (1999)
5b) Cognitive engagement with software leads to higher order thinking. Stoney and Oliver (1999), Dimock and Boethel (1999)	5b) Student reflection takes place in solitude, without the teacher's knowledge. Laurillard (1995, in Stoney and Oliver, 1999 online)
6) Computers help students take an active role in their learning. Maor and Phillips (1996)	6) Many students are guilty of following "Fatima's rules". (Aikenhead, 2000)
7a) Supportive role of the teacher helps the use of computers as a learning tool. Maor and Taylor (1993)	7) There is no discussion or reflection between the student and computer. Laurillard, (1993, in Maor and Phillips, 1996, online)
7b) Computer databases in a social constructivist learning environment enhance higher order thinking. Maor and Phillips (1996); Maor and Fraser (1999)	

Wilson (2000), when researching the teaching and development of thinking skills in Scotland, inferred that evaluation studies are inconclusive, and recommends that further research into computer-student interaction and collaborative learning be conducted.

1.3 RATIONALE FOR THIS RESEARCH

In 2002, I attended the International Conference on Computers in Education in Auckland. The conference theme "Learning Communities on the Internet - Pedagogy in Implementation" spawned over 400 papers. Many of these detailed how ICT can be applied to higher order thinking skills, including Agnew (2002), Lee (2002a) and Thomas (2002). Agnew (2002) iterated that researchers have tried to evaluate whether or not the use of technology has a major impact on student learning. Agnew (2002) continues by explaining that students are encouraged to develop higher order thinking skills, and that the results have been significant. However, no formal statement about how the achievement of these skills have been observed or measured has been made. Sherry and Jesse (2000) suggested that while educators seem to inherently 'know' that technology increases student achievement, measuring the increase is challenging. Branigan (2000, in Sherry & Jesse, 2000, p. 2) reported that in cases where teachers have applied a high degree of technology within the classroom, standardized test scores also were high. As schools have a far more important role than simply producing good test scores these results do not necessarily provide insight into overall student development. Sherry and Jesse (2000) suggested that we need to measure student motivation, metacognition, inquiry learning and the application of the students' skills.

While technology surfaced in schools during the 1950s, in the form of valve-powered television and radio, the use of computers as a teaching/learning tool did not occur until about 1975 (Murdock, 2004). In parallel with the development of computers in education there has been increased research into the nature of learning environments (Chang & Fisher, 2003; Newby, 1998). Examining the relationships between learning environments and the use of technology to develop higher order thinking skills addresses the concerns highlighted in Table 1.2.

To gain a better understanding of what is happening in a technology-rich classroom, it is necessary to determine the dominant pedagogy; the availability of technology and its perceived value; and the relationships that exist between the teacher and students. This research answers the following questions:

Q1 What is the relationship between technology-rich learning environments and the development of higher order thinking skills?

Q2 To what extent are higher order thinking skills demonstrated by students in a technology-rich environment?

This encompasses the following questions.

1.4 RESEARCH QUESTIONS

1. What is the relationship between student perceptions of technology-rich learning environments and
   1.1. their attitude towards computers?
   1.2. their level of technological skill?
   1.3. the teacher-student relationship within that learning environment?
   1.4. the development of critical higher order thinking skills?
   1.5. the development of creative higher order thinking skills?
   1.6. length of time spent within the environment?
   1.7. the age of the technology?

2. What is the relationship between student attitudes towards computers and the
   2.1. level of technological skill?
   2.2. teacher-student relationship within the learning environment?
   2.3. length of time spent within the environment?
   2.4. age of the technology?
   2.5. development of critical higher order thinking skills?
   2.6. development of creative higher order thinking skills?

3. What is the relationship between students' computer skills and the
   3.1. teacher-student relationship within those learning environments?
   3.2. development of critical higher order thinking skills?

3.3. development of creative higher order thinking skills?

3.4. length of time spent within the environment?

3.5. age of the technology?

4. What influence do teacher-student relationships have with respect to the
   4.1. development of critical higher order thinking skills?
   4.2. development of creative higher order thinking skills?

5. Is there a significant correlation between the length of time spent within technology-rich environment and the development of
   5.1. critical higher order thinking skills?
   5.2. creative higher order thinking skills?

6. Is there a significant correlation between the age of the technology and the development of
   6.1. critical higher order thinking skills?
   6.2. creative higher order thinking skills?

7. What is the relationship between students' development of creative higher order thinking skills and their development of critical higher order thinking skills?

1.5 METHODOLOGY

1.5.1 Research Design

The research method is based within a social constructivist learning framework. This assumes that learners construct their knowledge through experience and by reflecting on those experiences. The perception of social constructivists is that all knowledge is constructed by the socialisation of individuals (Ernest, 1995). Sing (1999) argued that socialisation allows individuals to experience cognitive conflict, and therefore also experience the confirmation or modification of existing beliefs.

The approach taken by this research is that of a case study. Case studies focus on questions of 'how', 'who', 'why' and 'what' within a real-life context (Burns, 1997). Data are usually, but not exclusively, drawn from observations and analysis of documents within the case environment. While the main interest lies in exploring the idiosyncrasies of the social structure being examined, this does not prevent the results being generalised. Cousin and Jenkins (2001) stated that case study research supports a mix of quantitative and qualitative methods. In doing so it supports the organisation of social data, preserving the characteristics of the environment from which the data are gathered.

1.5.2 Data Sources

The data source was the Year Nine student cohort in a metropolitan, independent girls' school, providing a sample size of approximately 150 students. This school had been implementing a notebook computer program for nine years, in which all students in Years Five through to Year Ten use their notebooks across all learning areas, every day at school. The majority of students enrol in the junior years, although about one third of students begin in Years Seven and Eight, and approximately twelve students enrol in Year Nine. The Year Nine cohort constitutes students that have had between one and five years exposure to the technology-rich learning environment. Some students will buy a new notebook computer after three years; others will economise by keeping their original notebook computer for six years (Foord, 2005). Data about the length of enrolment at the school, and the age of their current notebook computer, are held within the school's databases.

1.5.3 Data Collection

The instruments used were the

- *Computer Laboratory Environment Inventory* (CLEI);
- *Attitude towards Computers and Computer Classes* (ACCC);
- *Australian Schools Computer Skills Competition* (ASCSC);
- *Questionnaire on Teacher Interaction* (QTI);
- *Ennis' Weir Critical Thinking Essay Test* (EWCTET); and
- *Scientific Creativity Structure Model* (SCSM).

The first two instruments, CLEI and ACCC, are usually presented as one instrument. The ASCSC is an externally prepared test that students sit annually. It is used to provide data about the students' computer skills in Year Nine. The EWCTET and SCSM are a part of the Year Nine students' integrated curricula. Data concerning students' length of enrolment at the school, and the age of their computers, is available from the school's databases. Data collection took place over three school terms.

Classroom observations took place in classes utilising technology to achieve a subject specific learning goal. Some of these classes were videotaped, allowing them to be studied in greater detail when considering the individual responses of students to set tasks, and the social interactions of the students.

The CLEI and ACCC are survey instruments developed within Western Australia. The QTI was originally developed in The Netherlands (Wubbels & Levy, 1993) and has been modified within Western Australia. These instruments have been used in many national and international studies of learning environments (Fisher, Fraser & Cresswell, 1995; Fisher & Stolarchuk, 1998; Fraser, 1989; Fraser, McRobbie & Fisher, 1996; Newby, 1998; Nickell & Pinto, 1986; et al.). The EWCTET requires the student to formulate a complex argument in response to an earlier argument. In doing so the test measures the student's ability to analyse an argument and provide a logical, coherent response, including creative and critical dimensions (Ennis & Weir, 1985). In a later paper (Ennis, 1998) the test is reported as being valid and reliable, with inter-rater reliabilities in the order of 0.72 – 0.93. The SCSM is a relatively new instrument modelled on the *Torrance Tests of Creative Thinking* (TTCT), developed by Hu and Adey (2002). This test allows creative thinking to be examined within the context of science education.

1.5.4 Data Analysis

The QTI, CLEI and ACCC provide individual students perceptions of aspects of the learning environment measured on a five-point Lichert scale. The ASCSC and EWCTET were marked according to predetermined answers keys. Whilst the ACSCS marking key is prescriptive the EWCTET allows for teacher judgment. The SCSM marking is open-ended. All of these instruments provide a raw numerical score. Data analysis involved the correlation of results to determine the relationships that exist between the different learning environment factors. Preliminary analysis used a commercially available spreadsheet to format, group and graphically represent data, and to link the different data sources. Further statistical analyses were performed with the *Statistical Package for the Social Sciences* (SPSS) program.

1.6 SIGNIFICANCE OF THIS RESEARCH

In 1998 Newby conducted research into the effectiveness of computer laboratories as learning environments. As such, it was one of the first models to examine computer-based learning environments (Newby, 1998). Earlier research has examined aspects of computer applications in the classroom (Milheim, 1995; Solomon, 1993a; Swain, Greer and van Hover, 2001, et al.). Some researchers (for example, Jonassen, 1996) have associated technology use with higher order thinking skills. This area of research is in its infancy, and little has been conducted within Western Australian secondary schools.

Maor and Taylor (1993) stated that the data available that examines computer use and higher order thinking does not consider the influence of the teacher or the pedagogy employed. The proposed research will add to this body of knowledge by investigating the relationships between the use of technology, pedagogy, teacher-student relationships and the development of thinking skills. Furthermore, it will be conducted within a Western Australian school.

A study by Daley, Watkins, Williams, Courtenay, Davis, and Dymock (2001) demonstrated that qualitative methods without quantification will provide suspect data. The same allegation can be levelled at quantitative techniques that have no qualitative backing. Anderson (1998) states that whatever data are collected, they must be both valid and reliable. These factors rely on the methodological approach to data collection and the collecting instrument. Maor and Fraser (1993) argued that there is a need to combine qualitative and quantitative research methods, in order to provide a multidimensional understanding of the classroom learning environment.

This research combines quantitative and qualitative research methods. The CLEI, ACCC, QTI and ASCSC allow for the quantifying of classroom environmental factors, albeit they are based on individual, subjective beliefs. The verification of these data are made possible through direct observation of the environment; are the student perceptions and attitudes supported by their classroom behaviour?

This project has significance for a number of parties. These can be placed into two groups: The learning community in which the research is embedded, and other researchers. Within the learning community the results have relevance to the parents, teachers, students and the school council. Parents need to buy a notebook computer for each daughter in Year Five through to Year 10. At a cost of about $3,500 each, parents want to know that the notebooks make a difference, and they want to know that their use is monitored. Similarly the school council, responsible for overseeing the development of the whole College, needs to see how resources are being used, and how they can be used better and/or further developed.

Pockets of students and teachers sometime query why computers are needed. Again, the research results should demonstrate the level of effectiveness of technology in enhancing learning. Participating staff may choose to use elements of the research as a means of reflection on the teacher-student relationships and effectiveness of ICT in their classroom, and possibly as a basis for their own classroom-based action research.

The research took place in a single sex (girls), high socio-economic status (SES), non-Government, Uniting Church affiliated school. There are many similar schools in Perth and other major cities. Those that have adopted a notebook program could use the results of this research as a starting point for their own inquiries. Schools contemplating the introduction of a notebook program could refer to the results as a means of guiding their programs. The nature of the project allows it to be easily adapted to boys' schools, co-educational schools and schools from different socio-economic climates.

Tertiary institutions are also examining the application of notebook and/or hand-held computers within their faculties. Edith Cowan University is in its second year of trialling notebook computers with staff and students ("Portable computing is catching on", 2005). In 2005 elements within Curtin University trialled Personal

Data Assistants (PDAs) with staff and students (Trinidad, 2005, pers. com.; McMahon, 2005, pers.com.; Hewlett-Packard, 2004). These are not necessarily within computer classes – they are looking at the applications of the technology to the advancement of student learning. In some respects both of these projects parallel the undertakings of this research. The continuing evolution of technology within education ensures that this research will remain relevant for the foreseeable future.

The use of the SCSM as a means of collecting data related to students' creative thinking is relatively new. It has been used in studies conducted in the United Kingdom and China. At the time of writing, it has not been used in Australia. By implementing this instrument in Australia, data that further verifies or disputes its reliability can be gathered.

1.7 LIMITATIONS OF THIS RESEARCH

In broad terms the limitations of the research can be divided into two groups: Those that relate to the general methodology, and concerns about specific processes.

Newby (1987) suggested that a weakness of case study research is that aspects of the environment are only measured once. There is no pre- and post-test sampling. In order to get a true representation of the students' perceptions the environment should be sampled periodically. By way of example, results for the Anxiety scale within the ACCC could be expected to be different at pre- and post- exam times. While the school involved in the case study has expressed an interest in tracking a particular year cohort over several years, this is not the same as repeated sampling within one year.

Data for this research were gathered from a single sex (girls), high SES, independent, Uniting Church affiliated school. This is not a typical scenario for a high school in Western Australia. Consequently, the conclusions may not represent the general situation across the State, and the significance of the research may be compromised. Associated with this limitation is the population sample size. One hundred and fifty students from a State-wide cohort of approximately 28,000 (Australian Bureau of

Statistics, 2005) appears relatively small. Taken from one year group, it may be argued that results from this sample should be interpreted with caution.

As a senior teacher within the school used as a case study, it is my responsibility to develop and deliver courses that use technology to enhance learning. An often-quoted maxim comes to mind: "lies, damned lies, and statistics" (attributed to Disraeli, n.d., in Twain, 1924, p. 246), this aphorism points out that with the correct statistical manipulation data can be made to demonstrate whatever the researcher chooses. With this in mind one has to be extremely careful not to let researcher bias influence the survey findings.

Two of the instruments, the CLEI and ACCC, were originally designed to be applied within the tertiary education sector. Specifically, to investigate the psychosocial perceptions of tertiary students enrolled in computer science courses. This raises two important arguments. It is possible that rewording the questions for use at the secondary level may have changed the validity of the scales. Removing elements of the questionnaires that are not deemed relevant influence the validity of the overall instrument. The modified CLEI and ACCC were applied to students in a technology-rich environment. In this setting, notebook computers are used as a tool for enhancing learning in eight learning areas (Parker, et al., 1998). The emphasis of these classes is on the application of computers rather than learning about computers, which was the original intent of the instrument.

The SCSM is a relatively new research instrument. While there is data available that supports the reliability and validity of the instrument (Hu & Adey, 2002) critics could argue that the conclusions related to creativity measured within science education might not depict an accurate model of creativity in a general population.

1.8 THESIS SUMMARY

The following chapters can be divided into four sections. Chapters Two, Three and Four present the theoretical background for this research. Chapter Two examines the current beliefs with regards to thinking and learning, and how these beliefs can be applied in the classroom. It concludes with a definition of higher order thinking that is adopted for this research. Thinking involves using the brain; biological models of thinking, learning and memory are described in Chapter Three and are linked to current pedagogical models. The role of technology, specifically, computer-based technology, is described in Chapter Four. Arguments supporting and opposing educational technology, and therefore its effect on higher order thinking, are presented.

A review of the relevant literature is presented in Chapters Five, Six and Seven. Chapter Five presents a study of learning environments and how they can be assessed. This is closely linked to Chapter Six, which investigates means of measuring technology use within a learning environment, and measuring higher order thinking skills. The advantages and disadvantages of various instruments are discussed, providing reasons for the selection of specific instruments used in this research. Chapter Seven provides a summary of five case studies in which aspects of higher order thinking have been examined. These case studies highlight the need for quantitative and qualitative data collection and analysis.

The methodological approach is discussed in Chapter Eight. Advantages and disadvantages of the case study approach are outlined. This is followed by a detailed description of how the instruments were administered, and therefore how data were collected. A description of the statistical tests, and the reasons for using them, is provided. For reasons of clarity, the research questions addressed by the different instruments are presented as a matrix.

The final section collates, statistically analyses and discusses the research data, and concludes with the answers to the research questions. Chapter Nine presents and analyses the data pertaining to the reliability of the research instrument. Chapter Ten includes data used to determine the technology-rich nature of the research environment. It is within this technology-rich environment that the research instruments are implemented. The results and their discussion are presented in Chapter 11. Data are presented in tabular and/or graphical forms, where relevant. Finally, the answers to the research questions are presented in Chapter 12. Their significance and recommendations for future research and applications, along with the limitations of the research, are discussed.

CHAPTER 2

HIGHER ORDER THINKING

2.1 INTRODUCTION

The broad definition of higher order thinking presented in Chapter One does not adequately describe the rich qualities of higher cognition. The first part of this chapter presents the changes in understanding of higher order thinking as society itself has changed. This culminates in a definition of higher order thinking on which the remaining thesis is based.

2.2 DEFINITIONS OF THINKING

The opening years of the last century saw the research and publication of a socio-anthropological study by Sumner (1906). Often referred to as a social Darwinist, Sumner regarded critical thinking as an essential prerequisite for human welfare – "Men educated in it cannot be stampeded by stump orators and are never deceived by dithyrambic oratory" (p. 633). Sumner touched on the concept of social constructivism by suggesting that, when thinking collaboratively, human minds allow the development of new knowledge. His comments that teaching in the form of catechism (i.e., rote learning) will not allow the attainment of critical thinking introduces a possible hierarchy of thought.

Ivie (1998) pointed out that although the literature pertaining to education is rampant with references to higher order thinking skills there is little attempt to clarify their definition, or how they should best be taught. Ivie continued, highlighting that questions of a higher order nature are generally isolated and only refer to solitary concepts or skills. Ennis (1987) suggested that the concept of higher order thinking is too ambiguous to be applied to schools, as its nature provides teachers with very little guidance. A rather cryptic extrapolation is provided by Resnick (1987) who asserted that, although it may be hard to define higher order thinking, most teachers recognise it when they stumble across it in the classroom. Chadbourne (1995) expressed reservations that this will occur. When discussing the influence of tertiary selection on Year 11 and 12 programs he commented that "Teaching tends to be a headlong rush through the crowded curriculum with little time for higher order thinking skills" (online).

The expression *higher order thinking skills* implies that there must also be lower order thinking skills and that these skills lie on a continuum. The word *skills* further implies that elements within this continuum can be taught (Wilson, 2000). Before differentiating between *lower* and *higher order* skills the various interpretations of *thinking* need to be examined.

Phillips (1993) listed a range of types of thinking, including analytical thinking, conceptual thinking, creative thinking, critical thinking, deductive reasoning, inductive reasoning, lateral thinking, logical thinking and reflective thinking. Reading through this array it is possible to establish casual links between some of the elements. Dictionary definitions (*The Macquarie Dictionary*, 2001) suggest that analytical thinking overlaps with critical thinking; logical thinking with deductive reasoning. Yet at no stage has *thinking* been clearly defined. The varied interpretations of thinking mean that defining higher order thinking would be, at best, arduous and erroneous. A quick Internet search for the expression "What is thinking" associated with educational sites resulted in 10,700,000 web sites (http://www.altavista.com, 2005). Similarly, a search for "definition of thinking" resulted in 1,360 web sites (http://www.google.com, 2005). To identify the nature of higher order thinking skills, this section will examine the ways in which thinking has been defined from the early Greek philosophers up to the present.

Socrates (circa 470 - 399 BC) recognized the value of asking profound questions before an idea is considered acceptable (Paul & Elder, 1995). His method of inquiry has been referred to as the Socratic Method (Ross, 1993). This method required a questioner to ask a series of questions that could only be answered "Yes" or "No". In doing so, the questioner would attempt to make the questionee contradict himself and thus negate his argument. A similar practice is demonstrated in many courtrooms throughout the world. This dialectic approach allowed Socrates to demonstrate the need for lucidity and logical uniformity within the thinking process. In doing so he established the basis of critical thinking, specifically, to challenge common beliefs via reflection.

This reflective process allowed Socrates to recognise, albeit by an unknown process, that whatever he perceived through the senses was somehow added to by his own mind (Edwards, 1972a). This led him to conclude that knowledge is the product of sensory perception and thinking.

Plato (c428 - 347 BC) believed that thinking was either a dialogue with one's soul or a spiritual activity to determine the relationships between his Forms (for example, triangularity and colour). Plato viewed Forms as being independent of the world although they exist within it (Edwards, 1972b). As they are separate from sensed experiences it is difficult to conceive how one would be able to learn about the world by attempting to study concepts that cannot be sensed. Plato further believed that knowledge is not subject to change. This seems to be a rather naïve stance, making no allowance for knowledge that, while initially accepted, is later found to be based on error. Plato himself adopted the *Four Element Hypothesis* described by Empedoclese in 400 BC (O'Connor & Robertson, 2000), which we now know to be a most simplistic explanation of physical chemistry. While this early hypothesis supported the contemporary thoughts about nature, its gradual replacement negates Plato's belief that knowledge cannot change. Critical thought, supported by rigorous scientific procedures, leads to the development of new knowledge.

Aristotle (c384 - 322 BC) argued that there are two basic forms of thinking, contemplation and deliberation (Edwards, 1972c). These thinking processes can be executed intelligently or poorly. This argument was based on Aristotle's belief that the structure of the world is such that it can be understood by logical examination. Contemplations, said Aristotle, led to conclusions whereas deliberations led to decisions. Both concepts are intertwined during our thought processes and one could argue that there is no real difference between reaching a conclusion and making a decision.

However, Ryle (1949) contended that according to Aristotle it must be possible to develop intelligent thought from unintelligent sources. To reach an intelligent conclusion or decision requires that the thinker has undergone earlier theoretical operations, which must also be intelligent. This argument extends backwards *ad* *infinitum*. As there cannot be intelligent thought derived from nothing, it must be possible to generate intelligence from non-intelligent precursors.

In his *Summa Theologica* (c273), Aquinas further developed Aristotle's idea of critical thinking (Edwards, 1972d). He applied a system of stating, judging and responding to all criticisms of his ideas as part of the development of those ideas. Aquinas would state a general topic; for example, "Whether there are ideas?" This is followed by a series of assertions refuting the original statement, and then by an argument opposing the assertions. This final argument and associated conclusions contains Aquinas' views (Halsall, 1996).

Aquinas' approach can be considered an early example of metacognition; the process of organising, evaluating, and monitoring one's own thinking. Metacognition is considered by Cotton (2001) as the peak of mental processing. Aquinas exemplifies that critical thinking does not have to result in the rejection of thoughts or beliefs other than those that are lacking in a logical base (Paul & Elder, 1995).

Probably the most often quoted reference to thinking is that from the 1641 treatise Meditationes de Prima Philosophia by René Descartes – *cogito ergo sum* (Ribeiro, 1998). "I think, therefore I am" arose from Descartes' principle of hyperbolic doubt, which addressed his mind-body problem. This principle states that if a proposition has no reinforcing evidence it must be false. Descartes doubted everything that could be doubted yet he was unable to doubt his own being. He reasoned that something had to exist to be able to doubt its own existence. Paul and Elder describe Descartes' work as the second text in critical thinking, the first being attributed to Bacon (1605, in Paul & Elder, 1995, online). His model of critical thought is based on systematic analyses of the epistemic primitives pertaining to a particular argument. When thinking critically one needs to constantly question and re-evaluate one's conclusions.

The period of time referred to as the Enlightenment (1700-1789) saw a further development of critical thinking. Bayle, Diderot, Montesquieu and Voltaire argued that deductive and inductive reasoning allow humans to increase their understanding of socio-cultural and political knowledge (Paul & Elder, 1995). This thinking requires the thinker to examine the weaknesses and strengths of the thoughts – a metacognitive approach. Building on Socrates and Descartes, the philosophers of the Enlightenment gave high regard to the systematic analysis and review of statements.

Thinking was portrayed by Bartlett (1932) as a combination of interpolation, extrapolations and reorganisation. Thinking allows us to join together ideas by finding the missing links between concepts. New understanding is achieved by synthesising the linked concepts and reorganising them. Bartlett demonstrated that rather than simply regurgitating ideas, students redesigned them based on their prior experiences – “An organism has somehow to acquire the capacity to turn round upon its own ‘schemata’ and to construct them afresh” (p. 208). Bartlett could be considered as an early constructivist. This is expanded by Mayer (1977, in Phillips, 1993, online), who suggested that thinking has three main components. Mayer described thinking as involving an internal system that uses a set of knowledge operations. The manipulation of these operations results in behaviour that is focussed on solving a problem. The association between cognition and behaviour has been further studied by Lowery (1988) and Roth and Lawless (2001), and is examined later.

Fraenkel (1980) considered thinking to be the development of ideas by organising data in a particular way and integrating it with life experiences. This designation, along with others, has been used in Malaysia to develop the Peningkatan dan Asuhan Daya Intelek (PADI) program, which translates to Program for Instruction in Learning and Thinking Skills (Phillips, 1993). This program presumes that thinking necessitates the manipulation of cognitive skills. The goals of thinking are seen as decision-making and problem solving. Like the works of Wilson (2000) and Cotton (2001) referred to above, the PADI program is based on the premise that cognitive skills can be taught and refined.

Beyer (1985) described thinking as the process of verifying the validity, accuracy and value of a belief or fact. This process encompasses a range of cognitive sub-skills, including the ability to differentiate between demonstrable facts and beliefs integrated with the ability to ascertain the reliability of the source. He identified conation and cognitive activities as key components of thinking. In later work Beyer

(1988, in Frampton, 1994, online) specifically referred to analysis and synthesis as examples of higher order thinking.

Chipman and Segal (1985) acknowledged that there is no singular accepted theory than can encapsulate thinking within one framework. They suggested that thinking is considered with respect to organised, non-impulsive behaviour, knowledge acquisition and problem solving. In some respects this broadly re-categorises the taxonomy of Bloom, Englehart, Furst, Hill and Krathwohl (1956). Chipman and Segal (1985) maintain that the gap between acquiring knowledge and using it in new situations requires well-developed problem solving skills. It should be possible, they argued, to design learning activities that will increase the emergence of these skills.

Thinking skills should be embedded within the discipline on which the thinking is based (Hudgins & Edelman, 1986). The discipline can be quite generalised; higher levels of thinking become evident when students debate a subject that includes a question or questions to be answered. The critical element is the ability to substantiate a point of view.

Amongst other examples Chance (1986) described the approach of de Bono (1979, p. 11) as part of his Cognitive Research Trust Thinking Course (CoRT). When asked who would like to be given $5 a week to go to school, all students in a class of 30 students raised their hands. Responses such as "We could buy sweets" and "We would be like grown-ups" were elicited. After engaging in a Plus, Minus, Interesting (PMI) activity, students forwarded suggestions related to bullies taking their money or forfeiting pocket money from their parents. When the question about being paid to attend school was repeated, only one out of 30 students supported the idea. Chance (1986) provided a comprehensive definition of critical thinking, incorporating factual analysis; comparison and reorganisation of ideas with a view to defending and evaluating arguments, and solving problems. He argued that logic is often used to support a belief without close examination of a given situation (e.g., money for school attendance). Real analysis of a situation allows the student to apply analytical and perceptual thought.

The perspective argued by Tama (1989) is that critical thinking has two components: A means of reasoning that requires sufficient support for a belief and a reluctance to modify a particular belief without substantial proof for an alternative conviction. This argument supports the later opinions of Wilson (2000) and Cotton (2001), believing that thinking skills need to be explicitly taught to students. Tama maintained that this can be achieved by adhering to three principles. First, teachers need to encourage active learning, which is described as learning by doing within a group setting. Second, students need to verbalise their thoughts. Again, this requires a group environment and in doing so, their understanding of the subject is developed. Finally, students need to think about their thinking, a process that will undoubtedly coincide with Tama's second principle.

Parallels have been drawn between Bloom's taxonomy (Bloom, et al., 1956) and the thinking skills required for reading (Hickey, 1990). Hickey referred to lower order (recalling detail, sequencing events and recognising main ideas) and higher order (recognising cause and effect, distinguishing between fact and opinion, recognising purpose and bias) reading skills. Both sets are seen to incorporate a combination of analytical and evaluative processes.

Mayer (Mayer & Goodchild, 1990, p. 4) added to his 1977 definition, describing thinking as a dynamic and methodical process of assessing beliefs to develop knowledge. The dynamism arises as the thinker queries "Does this make sense?" and asks metacognitive questions such as "How does this relate to my existing beliefs?" Thinking is considered methodical in that the thinker applies logical processes to answer the above questions. In doing so the thinker can evaluate the data, either accepting, modifying or rejecting it. Mayer and Goodchild described a belief as a statement about an entity, or the relationship between two or more entities backed with supporting proof. They recognise evaluation of beliefs could follow divergent pathways, some of which may be unsuccessful.

Mertes (1991) regarded thinking as a cognisant and purposeful method of interpreting information and events. This requires the thinker to employ reflective attitudes that direct beliefs and behaviour. This set of attitudes is developed through individual life experiences and existing beliefs. Mertes recommended that higher level thinking should draw on different content areas. By embedding higher order thinking in studies of mathematics, literature and/or science, learning is contextualised and therefore enhanced.

A parallel is drawn between the process of critical thinking and the composition of prose (Mertes, 1991). The stages of initial creation and subsequent revision involved in writing are regarded as the same as those experienced when thinking critically. Significantly, it is the writer who decides when one stage has been completed and it is time to move on, thus demonstrating metacognitive thought processes.

Thinking is depicted by Scriven and Paul (1992, in Huitt, 1998, online) as a process that conceptualises data gathered from various sources to develop a belief or action. Data sources include first hand observations, personal experiences, communication and reflection. The conceptual process includes elements of data analysis, synthesis and evaluation. This definition is expanded (Scriven & Paul, 2003) to incorporate other modes of thinking, in which they include anthropological, economic, scientific, historical, mathematical, moral and philosophical thinking.

Ennis (1992) portrayed critical thinking as logical introspective thinking that focuses on generating beliefs. This description was largely developed by analysing the works of McCarthy (1992) and Norris (1992). McCarthy argued that there is a conterminous relationship between critical thinking, rationality, and morality. Critical thinking is considered (by McCarthy) in an episodic sense; rational actions are basically actions taken in response to critical thought. Norris contended that our understanding of critical thinking is inhibited by the psychology of human beings as well as by educational values.

Huitt (1992) classified the mental processes used in problem solving and decision-making into two groups that approximate a critical/creative dichotomy. One set of processes tends to be more uni-dimensional and task-oriented. The second group leans towards a holistic approach, embracing qualities such as intuition and visualisation. This distinction also corresponds to what is sometimes referred to as left-brain thinking (analytic, serial, logical, objective) and right-brain thinking (global, parallel, emotional, subjective) (Springer & Deutsch, 1993, in Huitt, 1998, online).

The grouping of thinking into ‘critical’ and ‘creative’ is often associated with the erroneous grouping of ‘good thinking’ and ‘bad thinking’. This probably stems from our linking these terms with the natural sciences and the Arts when constructing our mental images of these thought processes. This is frequently coupled with a learned bias towards the sciences and the logical/analytical approach of the scientific method. The flaw in this connection was highlighted by Duemler and Mayer (1988, in Huitt, 1998, online), who reported that students demonstrated greater success in problem solving when using a smorgasbord of logical, creative, convergent and divergent techniques.

A triarchic theory of intelligence proposed by Sternberg is outlined by Vitorovna (c1993). According to Sternberg, Grigorenko, Jarvin, Clinkenbeard, Ferrari and Torff (2000) the theory is based on the premise that students need to develop a technique for solving problems. In addition to information-processing systems this theory incorporates human experience and context. Three elements are identified: The componential, experiential and contextual sub-theories. Most relevant to this discussion is the componential sub-theory, which is divided into three parts, meta-, performance- and knowledge acquisition-components.

Meta-components are responsible for planning, controlling and evaluating processes used during problem solving. The performance components are those that carry out the problem-solving activities. Knowledge acquisition includes the encoding, comparing and combining of information whilst problem solving is undertaken.

Sternberg (1985) contended that creativity results from the perceptive use of the knowledge acquisition components and from feedback between the different components. This feedback has a greater probability of occurring if the knowledge components are well organised and interconnected. Sternberg asserted that the inductive reasoning necessary for creative thinking has seven stages, outlined in Figure 2.1. This seven-stage model extends the earlier work of Wallas (1926, in Johnson, 2000, p. 30), who offers a four-stage model in which a problem is perceived, considered, a solution is developed and verified.

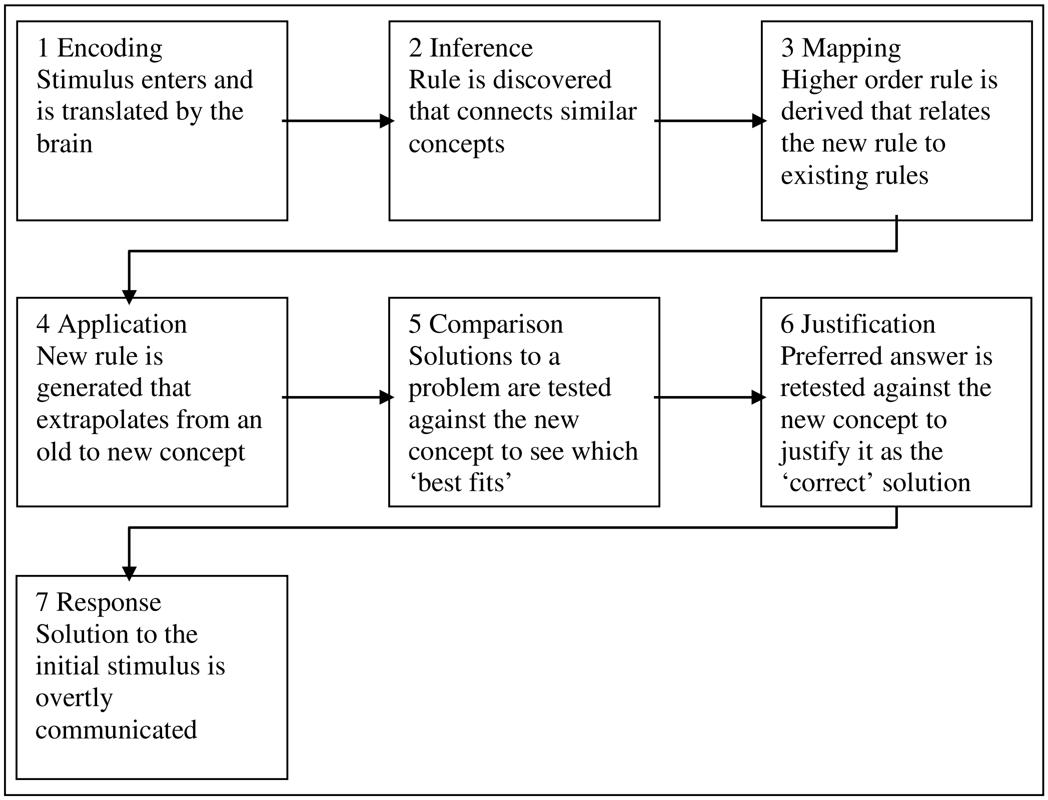


Figure 2.1. Sternberg's model of creative thinking.

Johnson (2000) maintains that this creative thinking process complements critical thinking. Furthermore, creativity must have some practical merit, which differentiates it from that which is simply bizarre.

Huitt (1998) has identified a potential crisis that arises from definitions similar to those provided by Beyer (1985) or Tama (1989). Where a description of thinking includes an emotive element (for example, verifying the value of a belief) it becomes difficult to separate cognitive skills from attitudes about those skills. In a later paper (Huitt, 1999) these two areas were shown to be closely entwined. Perhaps definitions of critical and/or creative thinking that ignore this affective component are incomplete.

The interaction of these components is further described in Figure 2.2 (Huitt, 1998, online). The model suggests that, in addition to the cognitive components of critical thinking, conative and behavioural facets must be considered. For the critical thinking process to be activated there must be a conative stimulus. Conation is described by Reitan and Wolfson (2005) as being the capacity to persistently utilise one’s skills when undertaking a problem-solving task. The adjective *persistently* implies a level of intrinsic motivation. The result is either confirmation of a prior belief or the construction of a new belief, which introduces the concept of creative thinking resulting from critical thought (see Chapter 3, p. 42).

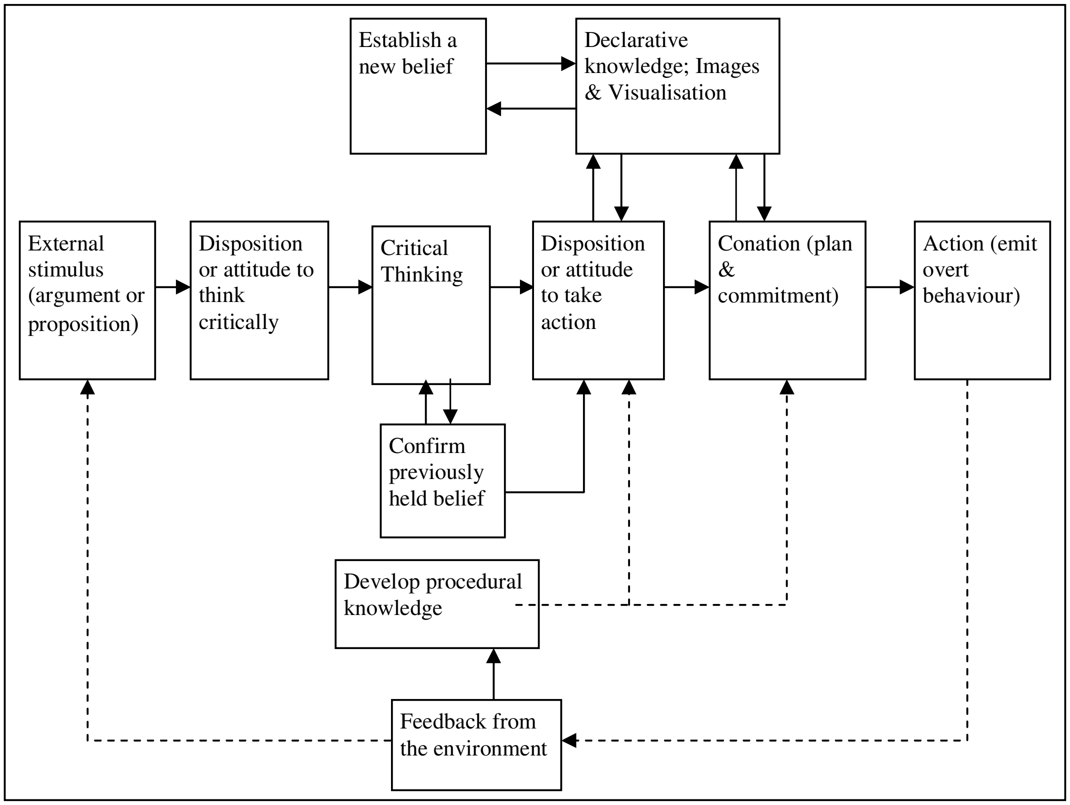


Figure 2.2. Huitt’s model of critical thinking.

An external stimulus provides a contention or suggestion to be evaluated. Unless there is an affective quality to initiate critical thinking, critical thinking will not be conducted. This model supports earlier definitions that include modules of conviction and/or behaviour. This will result in either confirming an existing belief or formulating a new one (Mertes, 1991; Scriven and Paul, 2003). This model draws on three forms of memory – procedural, episodic and semantic (Tulving, 1985, in Biggs & Moore, 1993, p. 221) – in association with a conative disposition to take action.

2.2.1 Bloom and Higher Order Thinking

Passey (1999) suggested that thinking skills can be categorised using a pre-determined structure such as that provided by Bloom, et al., (1956). Bloom's taxonomy of educational objectives describes a hierarchy of cognitive achievement commensurate with the contemporary psychological principles. Passey has listed a range of thinking skills that would be expected to be demonstrated at each of Bloom's levels, shown in Table 2.1 (Passey, 1999, online).

Table 2.1

Thinking Skills Associated with Bloom's Taxonomy

Bloom's Category	Associated Thinking Skills
Knowledge acquisition	Memorising
Comprehension	Questioning, discussing, explaining, doing
Application	Abstracting, transferring
Analysis	Categorising, characterising, comparing, contrasting
Synthesis	Collating, creating
Evaluation	Establishing relevance, judging

A recurring theme appears evident in the above attempts to define higher levels of thinking. The definitions cited all refer, in one or another way, to the cognitive levels described by Bloom. This is summarised in Table 2.2.

All of the definitions relate to the higher taxonomic descriptions of Bloom. Ennis (1987) stated that these are the higher order thinking skills. If Ennis is correct it can be assumed that the remaining taxonomic divisions refer to lower order thinking skills.

Table 2.2

Definitions of Thinking Associated with Bloom's Taxonomy

Bloom's Category	Thinking Skills Implied												
	Bartlett 1932	Fraenkel 1980	Mayer 1977	Chance 1986	Hudgins & Delman 1986	Sternberg 1986	Tama 1989	Hickey 1990	Mayer & Goodchild 1990	Mertes 991	Scriven & Paul 1992	Ennis 1992	Huitt 1998
Evaluation	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Synthesis		✓		✓	✓	✓			✓		✓		✓
Analysis	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓
Application						✓					✓		
Comprehension													
Knowledge acquisition						✓							

While the original taxonomy provides a linear progression, this is not reflected by all of the researchers' definitions. For example, Bartlett (1932) and Mayer (1977, in Phillips, 1993, online) both described the higher order thinking skills as containing elements of *analysis* and *evaluation*, bypassing *synthesis* on this linear scale. However, Hudgins and Edelman (1986) described the thinking skills in terms of *synthesis* only, ignoring the subsumed levels and ignoring *evaluation*. Conversely, Huitt (1998) acknowledged the requirement of the lower order skills in the achievement of the higher order. He stated that a specific knowledge base is a requirement for an individual to comprehend a given concept, an argument supported by Sternberg (1985).

Ivie (1998) was critical of this taxonomy, stating that it does not allow the teaching of thinking skills. But this was not an intention of the taxonomy. The taxonomy classifies the projected performance of students – "the ways in which individuals are to act, think, or feel as a result of participating in some unit of instruction" (Bloom, et al., 1956, p. 12). Bloom's taxonomy is concerned with elements of knowledge recall and the development of intellectual skills. As such, it reflects individual learning and memory processes employed during thinking. The utilisation of higher order thinking skills allows the attainment of higher levels of cognition.

In a similar vein, Beyer (1985) chastised researchers for equating thinking skills with Bloom's taxonomy. Thinking is seen as being both a frame of mind and a number of specific mental operations. However, his definition of critical thinking refers to the *evaluation* of statements. His description of the verification of *truth claims* refers to *analysis* and *synthesis*. Analysis, synthesis and evaluation constitute the higher levels of Bloom's taxonomy.

Research strengthens the argument that, while the first four levels in Bloom's taxonomy are linear, synthesis and evaluation could be reversed or divergent (Kreitzer & Madaus, 1994, in Anderson & Krathwohl, 2001, p. 289; Seddon, 1978, in Allen & Tanner, 2002, online). To quote Barr and Tagg (1995, p. 21): "Knowledge is not seen as cumulative and linear, like a wall of bricks, but as a nesting and interacting of frameworks."

Kagan (2005a) proposed a system in which thinking skills are divided into three categories labeled understanding, transforming and generating. Based on an input-processing-output model this system is reminiscent of the information processing model favoured by behaviourists (described later). The thinking skills associated with this technique are outlined in Table 2.3.

Table 2.3

Kagan's Classification of Thinking Skills

Understanding (input)	Transforming (processing)	Generating (output)
Recalling	Analysing	Brainstorming
Summarising	Applying	Synthesising
Symbolising	Inducing	Predicting
Categorising	Deducing	Evaluating
Shifting perspective	Calculating	Questioning

This model does not differentiate between skills of lower or higher order. Kagan argued that a hierarchy assumes that the levels exists as discrete units, yet there are more processes than knowledge recall and comprehension involved in processes such as evaluation. This argument is largely derived from the work of Hilts (1995, in Kagan, 2005a, p. 3), in which it was demonstrated that removal of areas of the brain associated with the recall events had little impact on an individual's IQ. Prior to having his hippocampus removed a subject, referred to as Henry, was prone to seizures that resulted from a biking accident (Matherne, 1998). This line of argument forwarded by Kagan is based on research conducted on a sample size of one. This individual did not have a 'normally' functioning brain prior to surgery, which suggests that the reliability of the data is dubious.

At the time Kagan (2005a) was in press, a tutorial was being conducted for teachers in primary and secondary schools (Kagan, 2005b). The course materials include the following quote: "Developing thinking skills is more basic than content acquisition" (Kagan, 2005b, p. 2). To state that *A* is more basic that *B* implies that a hierarchy exists between the two entities. In this instance, certain thinking skills are seen as being more basic than others. Allowing for a trans-Pacific difference in interpretation, Kagan could have meant that developing the thinking skills outlined in the workshop are fundamental to learning and are more important than simple knowledge attainment. Either way, one can infer that Kagan has demonstrated the existence of a thinking skills hierarchy. Interestingly, whilst endorsing an anarchical model, other materials promoted at the seminar include titles such as "Complete Higher-Level Thinking Combo Kit" (Kagan, 2005b, p. 49) and access to a website specialising in, amongst other topics, higher level thinking (Kagan, 2005b, p. 53).

Roth and Lawless (2001) and Fraenkel (1980) discussed thinking in terms in terms of convergence and divergence. Convergent thinking involves the cognitive processing of information from known sources. It endeavours to unify thoughts from different starting points to reach a single conclusion. In many respects this reflects the characteristics of critical thinking – analysis, synthesis and evaluation. Divergent thinking uses what is already known to spawn new knowledge. In this approach the thinker starts from a given point and moves outwards – a process often described as creative thinking. While creative thinking can be considered to use Bloom's synthesis, it involves other processes that are not clearly defined, such as *imagination* (Jonassen, 1996).

2.2.2 Anderson's Revision of Bloom's Taxonomy

When considering the natures of critical and creative thinking it becomes apparent that they are not accurately portrayed by a strictly linear, hierarchical taxonomy. Research into the hierarchical nature of Bloom's taxonomy has been conducted by

Kropp and Stoker (1966, in Seddon, 1978, pp. 309-319). Four tests with groups of questions designed to address each level of Bloom's taxonomy were administered to 1500 students. Statistical examination of the data included applying the Guttman-Lingoes smallest space analysis. This procedure finds the lines of best fit within groups of data and the relative associations between groups of related data (Godwin & Canter, 1997). The *ideal* and *actual* relative groups for this analysis are shown in Figures 2.3 and 2.4 (Seddon, 1978, pp. 317-318).

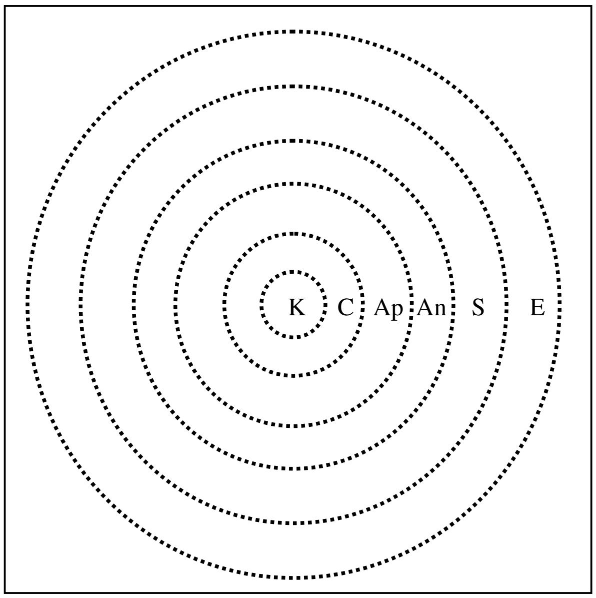


Figure 2.3. Ideal Guttman-Lingoes smallest space analysis model of Bloom's taxonomy.

The calculated lines of best fit for each level of Bloom's taxonomy in Figure 2.4 show a number of deviations from the expected results, if a strict linear hierarchy exists. A hierarchy does seem to exist between the levels of *comprehension*, *application*, *analysis* and *synthesis*. It is not strictly linear. The line of best fit for synthesis crosses the subsumed levels, giving further evidence to support the notions that the levels are not clear-cut. If the general boundaries (shown by the broken lines) are used to delineate Bloom's levels then *evaluation* can be added to the hierarchy, but *knowledge* remains as an isolated entity.

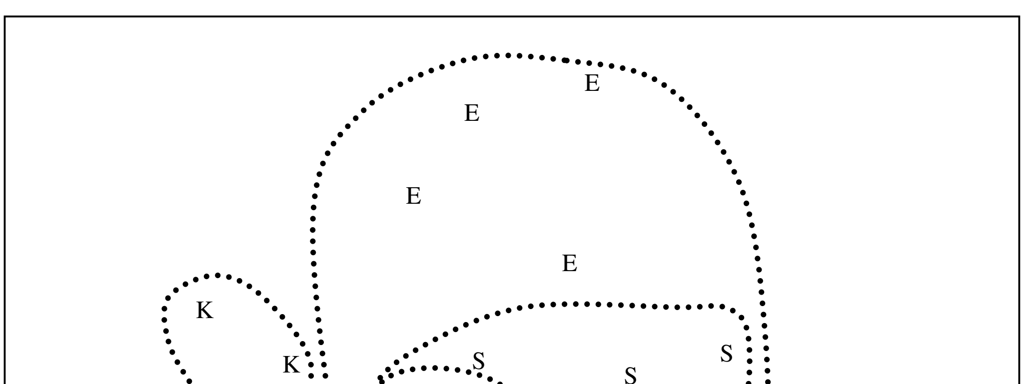


Figure 2.4. Actual Guttman-Lingoes smallest space analysis model of Bloom's taxonomy.

Anderson, a student of Bloom, has put forward a revised taxonomy, shown in Table 2.4 (Anderson & Krathwohl, 2001). The revisions include changing some of the category names (e.g., *comprehension* to *understanding*); reorganising the levels; and changing the headings from nouns to verbs. Verbs are used to emphasise that thinking is an active process. *Synthesising*, which Anderson closely links to creative thinking (Anderson & Krathwohl, 2001) is now placed at a higher level than evaluation.

Pohl (2000) suggested that creating new thought is more complex than the critical analysis (i.e., evaluation) of existing thought, and this revision is indicative of the increased complexity. It is possible to be critical without being creative, yet the creative process requires the ability to modify, accept and/or discard existing ideas. This idea supports the earlier work of Huitt (1998), whose critical thinking model in Figure 2.2 suggests that creative thinking results from critical thought.

Table 2.4

Anderson's Revision of Bloom's Taxonomy

Bloom's Taxonomy	Anderson's (Revised) Taxonomy
Knowledge	Remembering
Comprehension	Understanding
Application	Applying
Analysis	Analysing
Synthesis	Evaluating
Evaluation	Creating

Passey (1999) questioned whether higher order thinking skills, in a hierarchical taxonomy, should be considered cognitive or metacognitive. Passey described cognition as the ability to carry out a task and metacognition as an awareness and understanding of different approaches to completing the task. This question, posed in 1999, was based on Bloom's hierarchical taxonomy and not that of Anderson, whose revised taxonomy addresses the initial question.

The six levels described by Anderson are further divided into four groups: Factual, conceptual, procedural and metacognitive knowledge. These groups constitute the *knowledge dimension* while the six levels are referred to as the *cognitive process dimension* (Anderson & Krathwohl, 2001). Including the knowledge dimension recognises that in the process of student knowledge construction, teachers need to provide a degree of facts and/or data. It does not imply that knowledge is *only* a collection of facts; knowledge is defined as the organisation of these facts in accordance with constructivist theory. The Guttman-Lingoes plot shown in Figure 2.4 supports this argument. Knowledge acquisition lies outside of the concentric hierarchy formed by the other cognitive levels. The organisation and personal interpretation of knowledge will vary with the cognitive order used to process the knowledge.

Anderson's taxonomy recognises that knowledge fluctuates from explicit and relatively concrete to more multifarious and abstract, and within-level differences are significant for the other categories. Furthermore, complex tasks associated with one level will often be more difficult than the simple ones at the next higher level (p. 192), which this needs to be taken into account when a teacher is planning a unit or lesson. The result is a two dimensional matrix shown in Table 2.5.

Table 2.5

Two Dimensional Array of Anderson's Taxonomy

	Knowledge Dimension			
Cognitive Process Dimension	**A** Factual knowledge	**B** Conceptual knowledge	**C** Procedural knowledge	**D** Metacognitive knowledge
Remembering Understanding Applying Analysing Evaluating Creating	Basic terminology; specific details (e.g. chemical symbols and valencies	Classification; generalisations; knowledge of theories (e.g. Darwin/Wallace model of evolution)	Subject specific skills; knowing when to use a particular procedure (e.g. use of laboratory equipment, following the scientific method)	Self knowledge (e.g. recognising one's own knowledge level, identifying personal strengths and weaknesses)

Cotton (2001) pointed out that when students employ these higher levels of thinking, they are adopting risk-taking behaviour. The effects of the classroom environment on encouraging this behaviour should not be overlooked, particularly as the students' learning behaviour can be at a level different to that intended by the teacher. What may be presented as an evaluative activity may not involve evaluative thinking from all of the students (Anderson & Sosniak, 1994).

Anderson and Krathwohl (2001) argued that problem-solving tasks will draw on several levels simultaneously, yet these levels do not need to be hierarchic. The specific rows, columns or cells that the thinker employs will be determined by the nature of the set task. The historical definitions of thinking outlined above can be associated with the cognitive/knowledge dimensions of Anderson, shown in Table 2.6.

Table 2.6

Thinking Skills Embedded within Anderson's Hierarchy

Anderson's dimension		Thinking Skills Implied												
Cognitive	Knowledge	Bartlett 1932	Fraenkel 1980	Mayer1977	Chance 1986	Hudgins & Edelman 1986	Sternberg 1986	Tama 1989	Hickey 1990	Mayer & Goodchild 1990	Mertes 1991	Scriven & Paul 1992	Ennis 1992	Huitt 1992
Creating	Factual		✓		✓	✓	✓			✓		✓		✓
	Conceptual		✓		✓	✓	✓			✓		✓		✓
	Procedural		✓		✓	✓	✓			✓		✓		✓
	Metacognitive		✓		✓	✓	✓			✓		✓		✓
Evaluating	Factual	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
	Conceptual	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
	Procedural	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
	Metacognitive	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Analysing	Factual	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓
	Conceptual	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓
	Procedural	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓
	Metacognitive	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓
Applying	Factual						✓					✓		
	Conceptual						✓					✓		
	Procedural						✓					✓		
	Metacognitive						✓					✓		
Understanding	Factual													
	Conceptual													
	Procedural													
	Metacognitive													
Remembering	Factual						✓							
	Conceptual						✓							
	Procedural						✓							
	Metacognitive						✓							

2.2.3 Higher Order Thinking Skills

It appears that higher order thinking skills encompass the qualities assigned to the various definitions of critical and creative thinking. Marzano (1988) integrated these two divisions with metacognition when describing higher order thinking skills. Critical or creative thinking implies that there is some thinking involved about the thinking process. These divisions should not be seen as polarised but complementary.

The separation into criticism and creativity still allows each process to draw on skills embedded within the other, albeit with different emphases. The student needs to be able to organise information related to a given subject and recognise how this subject relates to others. The generation of new knowledge requires the ability to integrate existing ideas and make selections from a range of alternatives.

Burkhardt, Monsour, Valdez, et al., (2003) referred to convergent and divergent thinking with a strong association to the concepts of critical and creative thought. Convergent thinking uses elements of applicable and analytical thought during problem-solving, critical thinking processes. Divergent thinking relies on applicable and analytical thought processes during problem-solving, creative thinking processes. Ivie (1998) suggested that students exhibiting higher order thinking skills will integrate critical and creative thought processes. Resnick (1987) and Jonassen (1996) pointed out that there is no singular approach that can be taken when applying higher order thinking skills. Complex problems will yield many solutions, and thus higher order thinking is non-algorithmic.

All of these descriptions point towards higher order thinking skills as being the mental processes that let us achieve higher levels of cognition originally described by Bloom and revised by Anderson, including a metacognitive component. These can be grouped into critical and creative thinking. Perhaps the myriad of definitions arises through the erroneous attempt to specifically define a notion that has no specific definition. Higher order thinking skills should be considered in terms of their inherent qualities, which are shown by individuals when demonstrating higher levels of thought.

Burkhardt, et al. (2003, online) outlined the main qualities displayed by students who are higher-order thinkers. These include the ability to

- identify the core elements in a problem and the interaction between those elements;
- assign values to the core elements of a problem, and use those values to grade the elements in logical ways;

- build relationships between the core elements of a problem that provide insight into the problem;
- create and apply criteria to measure the strengths, weaknesses, and value of information, data, and solutions;
- create new solutions by combining elements of existing information; and
- (significantly for this study) use electronic tools to aid their data analysis.

2.3 SUMMARY

Learning is characterised by acquiring knowledge, skills, ideas and/or understanding based on those that were already held by the learner. Passey maintained that higher order thinking skills are at the core of learning. While it is possible to learn by rote (e.g., times tables) this requires little internal processing and may not lead to higher levels of thinking. A student, for example, who has rote learnt the ‘four times table’ but is unable to determine how many sheep a farmer has if there are seven sheep in each of four fields, has learnt only at a low level.

Resnick (1987) has stated that it is difficult to clearly define thinking. This has been demonstrated by the various definitions presented above. While different researchers place different emphases on aspects of thinking, they share common, general beliefs about thinking, as shown in Table 2.6. For the purposes of this thesis, higher order thinking skills are defined as those mental processes that allow students to develop factual, procedural, conceptual and metacognitive knowledge within the creative and critical domains described by Anderson and Krathwohl (2001). The addition of metacognition helps to address the need for the affective domain and conation to be included (Anderson and Krathwohl, 2001).

This is shown in Figure 2.5 (Norris & Ennis, 1989, in Pears, 1996, p. 66).

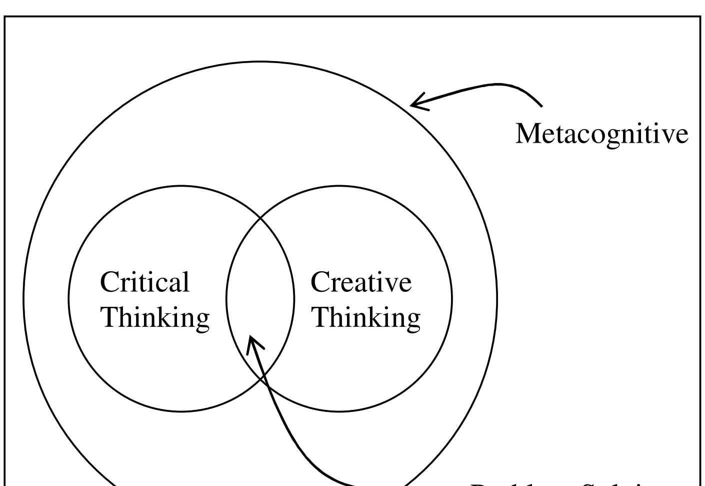


Figure 2.5. Interaction of critical and creative thinking.

A colleague once commented to me (Clarke, pers. com., 31st May, 2004) that cognitive psychologists work with the mind, while neural psychologists work with the brain. Thinking spans both of these domains. Therefore, in addition to cognition, neural processes related to thinking will be examined. Models of how thinking is believed to occur are presented in Chapter Three.

CHAPTER 3

BIOLOGICAL AND SOCIO-CULTURAL PERSPECTIVES OF THINKING, LEARNING AND MEMORY

3.1 INTRODUCTION

Leonardo da Vinci once stated "The good painter has essentially two things to represent: A person and that person's state of mind. The first is easy, the second is difficult" (da Vinci, n.d., in Gombrich & Rodgers, 1993, online). This quotation will be revisited later, following a description of the relevant processes of evolution and the central nervous system, relating them to the mental processes of thinking, learning and memory.

Piaget regarded life as a process of autoregulation (Piaget, 1971). In this respect the nervous system is seen as both a regulator of data input for the mind and as a means of transforming this data. Sensory perception has little value unless it brings about some action; therefore knowledge is not just a clone of reality but a reaction to, and transformation of, reality. Cognition, concluded Piaget, is the outcome of organic autoregulation (p. 26). The internal processes shown in Figures 2.1 and 2.2 (Chapter Two) are of a neurophysiological nature. The interaction of these processes with incoming data, and with each other, constitutes thinking (Maturana, 1980). Inevitably, this processing will bring about changes within the nervous system, specifically within the brain. It is from the brain that externalisation will emanate.

3.2 EVOLUTION

At a conference in Sydney, 2004, a question was put from the audience to Seymour Papert: "Why aren't we born with the higher knowledge that we need?" Certainly, we have the basic instincts to breathe and seek food when hungry, but why are we not born with knowledge of algebra or Boolean logic? The discussion leading to this question initiated from the observation that the rate of uptake of computer technology into classrooms was quite slow whereas most social evolution is quite rapid. The implication was that knowledge development has a closer link to biological evolution, given that the human brain has not structurally changed for thousands of years, although our technological development has increased exponentially (Papert, 2004). Aristotle (*Microsoft Encarta encyclopedia plus*, 2004) believed that although humans are born with a capacity to understand their world, they are not born with the details already in place. The discussion at the Sydney conference raises the question of how learning is to be attained.

The individual must first perceive the data necessary for learning to develop. An initially empty mind can learn within its environment, and thus quickly adapt to the environment (Lowery, 1998). This approach enhances a species' ability to survive even though the environment may change. Learning can be considered as a biological process in many ways similar to respiration or circulation (Leamnson & Betz, 1999). Raw ingredients provided by the environment are modified and incorporated into an organism by processes that change depending on the environment. Prior to a race breathing increases and the heart beats faster. At rest, both processes decrease.

Humans born into any environment will learn within that environment, based on their observations of, and interactions with, that environment. Lowery (1998) suggested that we are genetically designed with a thinking apparatus that is manifested periodically. The spacing of these periods allows new skills to be integrated into the organism. Consequently, a human is able to learn how to survive in any environment that supplies the basic biological necessities. In fact, our recent ventures into the hostile environment of outer space demonstrate that humans can learn to live in environments that cannot ordinarily support life.

Leamnson and Betz (1999) stated that organisms without a brain are still able to learn. Higher level organisms utilise a brain but do not abandon the learning mechanisms of lower organisms. Irrespective of the level of complexity of the organism, learning must embroil a nervous system. Other research by Aujila and Beninger (2001), Galambos (2003), Lowery (1998) and Maturana (1980) supported the idea that learning is intimately tied to our nervous system.

It is useful to compare the observations and conclusions of Maturana (1980) and Lowery (1998), concerning variation within the nervous system, with those of

Darwin and Wallace (Tomkins, 1998), concerning variation within a species shown in Figure 3.1.

Maturana & Lowery		Darwin & Wallace	
Observations	Inferences	Observations	Inferences
Prior to birth the body produces more neurons than it needs. (Lowery) Neurons connect via axons and dendrites with other neurons (Lowery)	There are enough neurons to allow the development of complex skills (Lowery)	The birth rate of a species exceeds that which can be supported by the environment There is variation between members of the same species	There is competition among members of a species for limited resources Some individuals are better suited to the environment than others
There is variation between the shapes of nerve cells (Maturana)	Variation between neurons is genetic (Maturana) Variation between neurons results from interactions of the organism with its environment (Maturana)	There is variation between members of the same species Each species maintains a relatively constant population	Those individuals with characteristics best suited to their environment are more likely to survive and reproduce
Approximately half of the neurons die before birth (Lowery)	The body eradicates unsound neural paths (Lowery)		

Figure 3.1. Darwinian theory and the evolution within the nervous system.

The comparison of Maturana and Lowery with Darwin and Wallace suggests that the development of thinking is an evolutionary process. Neural pathways that prove inefficient or inadequate are eradicated. Those that promote the development of the organism are enhanced. This evolution of natural learning has been described as learning in context (Churney, 2004) and involves interactions between the mind, body and environment. The interface is made up of our senses feeding data into the nervous system. The variation in neurons described by Maturana (1980) means that, while nervous systems resemble each other in broad terms, no two systems are identical. Evolution, or development of the mind, is occurring at a personal level.

Lowery (1998) added that structural and biochemical differences are emphasised by periodic changes of cellular growth and electrochemical activity of brains interacting with different environments. This is due, in part, to interactions with the environment, which is inextricably linked to human physical evolution. Bipedalism, opposable thumbs, stereoscopic vision and changes in brain morphology have allowed increased observation and interaction with the environment, and enhance the development of learning. The ability to learn, rather than to be borne with knowledge, has a clear survival advantage.

3.3 BEHAVIOUR

Huitt (1999) outlined three main psychological components of the mind; the cognitive, affective and conative domains. Cognition defines the interaction of processes that lead to the development of knowledge (questions of "What?"). The affective domain is concerned with the emotive analysis of knowledge and/or the environment (questions of "How do I feel?"). Conation is considered as a bridge between the former two domains (questions of "Why?") and, according to Huitt, it is a critical component of cognitive development. Conation explains how knowledge and emotions are translated into human behaviour. Learning and the ability to make decisions are more important to human cognitive development than reflex actions. Sternberg (1998, in Sherry & Jesse, 2000, online) argued that seeking answers to these questions of "Why?" are pivotal in activating thinking skills and can result in metacognition.

Bagozzi (1992, in Huitt 1999, online) suggested that cognitive research often cannot predict human behaviour because the conative element is not identified in the original research even though cognition and conation are intertwined. Zajonc (1980, in Chipman & Segal, 1985, p. 419) stated, "Contemporary cognitive psychology simply ignores affect". And yet the conatively based "Why?" questions have an important role in cognitive development as they direct the senses towards aspects of the environment deemed to be important (Heckhausen & Dweck, 1998, in Huitt, 1999, online).

Human behaviour, resulting from cognitive and conative changes, can be used as indicators of cognitive development (Roth & Lawless, 2001). Specifically, gesticulation reveals an interaction of sensori-motor action and cognition at abstract levels. Roth and Lawless (2001) described how students' verbal interaction, when discussing specific concepts, can be at a one level while their gestures used to elaborate their answers signify a higher cognitive level of understanding. The furrowed brows of players huddled over a chessboard and the movement of a student's eyes towards the right cerebral hemisphere when searching for an excuse for being late to class, provide windows into their thoughts, be they critically analytical or creative. These motor actions reinforce the notion that learning is a biological process. At this point it is worth requoting da Vinci, with the continuation of the second sentence: "The good painter has essentially two things to represent: A person and that person's state of mind. The first is easy, the second is difficult, for one has to achieve it through the gestures and movements of the limbs." (da Vinci, n.d., in Gombrich & Rodgers, 1993, online). Biology provides a means of interpreting worldly data and helps in the development of conceptual frameworks.

Lowery (1998) proposed that conation manifests itself through human pattern-seeking behaviour. Pattern seeking becomes a tool with which to learn about the environment. At a cognitive level, conatively induced pattern seeking allows the mental construction of sensory data input from the environment. Tripp (2001) has demonstrated that the hippocampus has a pivotal role in learning by integrating pattern seeking and cognition. This view is supported by the research of Ajula and Beninger (2001). It appears that the hippocampus mediates the transition of simple patterns into more complex systems thus assisting the broad learning process. More specifically, the hippocampus seems to be involved in the development of declarative memory, comprising episodic and semantic processes (Tripp, 2001).

Leamnson and Betz (1999) suggest that the patterns are made up of multiple pathways within the brain. Both the number and complexity of these pathways are immense; many pathways may be used in different connections. One pathway, or set of pathways, used to encode unrelated events could mean that there is a perceived relationship between the events, thus humans develop the concept of abstract thought.

This view of learning is described by Galambos (2003) as an evanescent process. The evolution occurs as a series of interconnected biochemical processes within an individual. It may further evolve as an individual is subjected to new experiences, but it is not transmitted to offspring in the Mendelian sense. The ability to modify existing knowledge requires that the knowledge is stored – a condition called memory. The acquisition of knowledge, and therefore of memory, results in synaptic changes within the brain (Aujla & Beninger, 2001).

3.4 BIOCHEMICAL INFLUENCES

Churney (2004) stated that the capacity of the brain to detect patterns allows for self-correction and, therefore, learning. Thinking (and learning and memorisation) occurs when there are biochemical reactions across synapses that result in the formation of neural networks. Mikulas (1974) described four sets of theories in an attempt to identify the nature of this biochemical activity. These theories are grouped under the headings of

- Neuronal-Synaptic Models;
- RNA-Protein Models;
- Glial Models; and
- Non-Connectionist Models.

3.4.1 Neuronal-Synaptic Models

This idea was first proposed in 1893 by Tanzi (in Deutsch, 1983, p. 367). These theories propose that the electro-chemical stimulus of a neuron will affect other neurons if they are within a given proximity. The effect will be to induce further electro-chemical activity in the adjacent neurons. The activity can be either exhibitory or inhibitory, depending on the chemicals involved. Over one hundred years later this premise holds true. Palastanga, Field and Soames (1998) state that a synapse allows the interaction of data from several different sources. The activity of one neuron may be influenced by many other cells; in turn, many cells may be influenced by the activity in one cell.

Deutsch (1983) demonstrated that conduction across the synapse is strengthened as a result of learning experiences. Galambos (2003) has shown that, while sensitisation leads to a stronger connection, habituation will weaken these connections. Memory results from the duration of these changes. The suggestion is that the receptor sites of the post-synaptic membrane become more sensitive to acetylcholine, and the degree of sensitivity is proportional to the level and type of learning. Research conducted by Aujla and Beninger (2001) suggested that a secondary messenger system, incorporating the cyclic adenosine monophosphate with dependent protein kinase (cAMP-PKA) may be necessary for the development of memoy. Their research demonstrates that the cAMP-PKA pathway could be affected by the neurotransmitter dopamine, thus stimulating or inhibiting the transference of learning into memory. Krug, Molle, Dodt, Fehm and Born (2003) have reported changes in creative and critical thinking associated with fluctuating blood concentrations of oestrogen. Higher levels of oestrogen were accompanied by an enhancement of convergent thought and a reduction in divergent thought, measured by analysing parallel dimensional complexity of electroencephalograph (EEG) activity.

Leamnson and Betz (1999) outlined how some axons will attach to other axons rather than forming the usual axon-dendrite synapse. These axon-axon connections act as switches to either inhibit or enhance the transfer of a biochemical signal. The act of concentrating causes the formation of axon-axon junctions to reduce interference from unnecessary sources. This focuses neural activity on the core source of interest.

Mikulas (1974) raised two problems with this group of models. First, neuronal-synaptic theories do not account for the different requirements of learning and memory. The system needs to have the flexibility to allow for changes in receptor site sensitivity and yet it also needs to have a degree of permanency, in order for learning to become a part of memory.

The second problem is centred on our understanding of the anatomy of the central nervous system. Purves (1994), Noback, Strominger and Demarest (1996) and Casey, Giedde and Thomas (2000) stated that, while the patterns of neural connection may change, there is relatively little cerebral growth after the first five years of life. Lowery proposed that learning objects are broken into components that are stored separately; for example, colour is stored in one place, shape in another, verbs are stored separately from nouns. A neuron that dies is not replaced and so any learning embedded in a neuron and its associated synapses may be lost. Associations between the separated areas would also be lost.

3.4.2 RNA-Protein Models

Watson and Crick first proposed the structure of deoxyribonucleic acid (DNA), leading to the central dogma of cell biology, which states DNA produces ribonucleic acid (RNA), which produces protein (Cooper & Hausman, 2004). RNA-protein theories of learning suggest that chemical activity within a synapse, resulting from a learning activity, affect the formation of RNA. Consequently, different proteins may be produced (Swenson, 1992). Some of these proteins can, in turn, affect the chemical activity of the synapse (Mikulas, 1974).

Research using *planaria* (McConnel, 1966, in Swenson, 1992, online) and rats (Jacobson & Schlecter, 1970 in Swenson, 1992, online) has demonstrated that when the RNA extracted from organisms subjected to a learning experience is injected into other organisms, they exhibit qualities of those learning experiences. Critics of this model argue that most of the extracted RNA is impure and any results could be due to these impurities – generally proteins or constituents of RNA (Swenson, 1992). There is also the problem of how injected RNA can integrate itself with the appropriate neurons in the recipient organism. Best (1968) suggested that if each neuron has a unique biochemical marker, this could be identified by a corresponding structure on the RNA molecule that has originated from the same site in another organism.

RNA models are supported by the research of Greenspan (2003), in which it is reported that inhibitors of RNA (and therefore inhibitors of protein synthesis) impede the development of long- term memory. According to Greenspan, RNA has a short duration in relation to memory. This implies that, in association with a RNA-protein model, it is necessary to have a method of encoding, or somehow perpetuating, learned experiences into memory. Greenspan (2003) suggests that there may be genetic control of synaptic changes leading to long-term memory formation.

3.4.3 Glial Models

Glial cells provide a supporting role for neurons (*glia* – Latin for *glue*). They are involved in structural support and providing nutrition (Nelson, 2002). The colour and structure of white matter within the central nervous system is due to the production of myelin by a sub-group of glial cells known as Scwhann cells. Myelin, a fatty material, provides protection for the axon and increases electrical conduction. As part of their research into RNA-protein theory, Hyden and Egyhazi (1963, in Swenson, 1992, online) reported increased levels of RNA in glial cells during learning experiences. Glial cell theories suggest that as these cells can control the electrical activity of neurons they may have a role in learning. Galambos (1961, in Mikulas, 1974, p. 33) suggests that glial cells provide the instructions to be carried out by the neurons.

3.4.4 Non-Connectionist Models

Unlike the previous models these theories do not require learning to have neuronal connections. Swenson (1992) expressed the idea that learning cannot be condensed to a series of synapses between particular neurons. A learning experience induces neurons to act in a logical pattern. Consequently memory is stored as a collection of electrical patterns emanating from a range of neurons; thinking becomes the release of electrical patterns that represent a memory. The precise neurons involved are irrelevant. The requirement is that enough neurons produce the necessary pattern.

Non-connector models support the views of Lowery (1998) when he described humans as pattern seekers. Neural images of the environment are not stored as photographs in an album. Images are broken into their components and stored separately. These components can be reassembled when recalling a memory. As no specific neurons are involved the loss of any given neuron is not as catastrophic when compared to the earlier three groups of models.

For example, should a person damage the nerves that control one arm the other is able to perform the ‘lost’ functions; a stroke victim that has lost the use of part of the brain can retrain other parts of the brain. In both cases, if learning required specific neural pathways then transfer of learning would not be able to occur.

Maturana (1980) suggested that neural morphology allows any given region of the nervous system to interact concurrently with many other regions. Consequently, all that is available at a given moment is the electrical activity that exists between neurons. Thinking, learning and memory can be considered as electrical states existing across neurons, independent of any given cell. Pribram (1969, in Swenson, 1992, online) demonstrated that this process is similar to that of holography. Neural activity produces electrical waves that will interact with other electrical waves, thus creating a multidimensional image. The components of different images can be recombined in different ways dependent on the neural activity, allowing the construction of new images as thinking takes place.

3.5 GENERATIVE LEARNING

The disassembling of images and separation of the components (Biggs & Moore, 1993) is analogous to the top-down approach of computer programming and the practice of writing programming modules that can be re-used. We have developed our approach to computing based on our perceptions of organic data processing. This gives computers the potential to extend our thought processes.

The nervous system allows interaction with the environment and expands the cognitive domain (Maturana, 1980). Viewing the environment from a new perspective (for example, turning a chessboard around half way through a game) will cause the growth of new dendrites to allow processing of the new data (Lowery, 1998). The thousands of dendrites arising from millions of neurons can result in billions of neural connections and associated electrical waves at any given time. Collectively these processes make up thinking. According to Roth and Lawless

(2001), neural structures and pathways are a support system for thinking and learning. While neurons make up the substrate that allows these thought processes to occur, it is the thinking that is of prime importance and not the biological components. Leamnson and Betz (1999) argued that the brain should not be considered as a permanently hard-wired like computer memory, into which data is simply added for later recall. During learning processes the brain is changed; neural connections that would otherwise be lost are stabilised.

The generative learning model can be considered as a biological process (Shepherd, Clendinning, & Schaverian, 2002). New thoughts are tested against those that already exist. Those that survive, the cognitively 'fittest' are kept, both modifying and strengthening the existing thoughts. Learning takes place within the context of the learning environment. Schaverian and Cosgrove (2000) suggested that, from this model, we can deduce six closely connected learning acts, summarised in Table 3.1.

Table 3.1

Learning Acts Derived from the Generative Learning Model

Learning Act	Description
Exploring	Select inquiries & prepare ideas relevant to the learner Test them against a background of values & prior experiences Identify personal learning goals
Designing	Evaluate tests currently available Select and develop criteria for tests that are appropriate in context
Making & Operating	Implement the criteria selected in the design phase
Explaining	Invent stories to make sense of what their tests revealed
Understanding	Bringing inquisitiveness to momentary rest before further ideas and tests are generated

Exploring recognises students' pre-existing abilities and allows them to create and test ideas through new experiences. Designing enables students to acquire methodologies from their culture and construct a scaffold in which their ideas may be tested. The selection process is guided by existing values and goals. The making and operating acts allows students to produce and apply a methodology that has value to them. Explaining requires students to communicate their new ideas, engaging higher order thinking skills as described by Jonassen, Carr and Yueh (1998). Pre-existing ideas, those generated from the testing process and those derived from peer communications are use to mould the students' knowledge. Understanding involves the adaptation of the generated knowledge into the students' environments.

Whichever model, or combination of models, described above that one chooses to accept as the best biochemical interpretation of thinking, it should be clear that learning, and therefore thinking, is intricately linked to the central nervous system, and is biological in its nature. By examining the relationships that exist between students within a learning environment, and the behaviours of the students, inferences may be drawn with regards to their thinking processes.

3.6 A LEARNING CONTINUUM

"The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Ausubel, 1968, p. 18).

3.6.1 Constructivism in the Curriculum

The introduction of outcomes based education in Western Australia has seen a renewed interest in the concept of constructivism. Constructivism is a theory that attempts to explain how people learn (Wilson & Liepolt, 2004). Learners construct their knowledge through experience and by reflecting on those experiences. A new experience has to be conciliated with the interpretations of prior experiences. This may change what we believe or reinforce an existing belief. Conversely, the new experience may be discarded.

For many teachers this challenges their epistemology, which, for many years, has been based on behaviourism. The predecessor to outcomes based education – the Unit Curriculum – required a system in which a lot of knowledge was (supposedly) transferred from teacher to students, as demonstrated by the heavy weighting of knowledge recall objectives for a typical unit curriculum science unit shown in Table 3.2 (Curriculum Branch, 1987). This emphasis on knowledge recall was contrary to the philosophy behind the Unit Curriculum, which promoted metacognitive activities.

Table 3.2

Assessment Structure for Unit Curriculum Science Units

General descriptors	Weighting
Knowledge	50% - 70%
Process skills	15% - 30%
Sensori-motor skills	5% - 15%
Affective outcomes	5% - 10%

The general differences between the behaviourist and constructivist approaches are described by McBeath and Atkinson (1992) and are summarised in Table 3.3.

Table 3.3

Differences Between Behaviourist and Constructivist Teaching/Learning Theories

Characteristic	Behaviourist	Constructivist
Learner Control	Learners have minimal control and are regarded as passive consumers	Substantial level of user control with learners regarded as active participants
Complexity	Highly structured material presented in simple formats to maximise the chance of positive feedback	Material that is typically complex, allowing a variety of content to be considered and a range of processes to be exercised
Challenge	Artificially contrived, extrinsic rewards	Intrinsic rewards gained by the completion of complex tasks

Boyle (2000) expanded the constructivist principles shown in Table 3.3, considering the theory to embody five components:

- Authentic learning tasks;
- Interaction;
- Ownership of the learning process;
- Experience with the knowledge construction process; and
- Metacognition.

Behaviourist approaches are often criticised for being outside of students' spheres of experiences, and consequently lack real meaning for the students. Authentic tasks will be fixed in problem-solving contexts relevant to the world of the students. Constructivist environments view the exchange of ideas, and the negotiation of meaning, as the basis for knowledge development, in which social interaction provides the foundations for learning (Huitt, 2000). Group discussion allows a range of perspectives to be considered by individuals, which assists in the construction of meaning.

A fundamental requirement for solving real-world problems is ownership of the problem. Boyle argues in favour of student-centred learning, in which students choose the problems and associated tasks that they will undertake. Student-centred learning also allows those involved to become experienced with knowledge construction. By selecting their own problems, and being involved in designing the problem-solving process, students are learning about how they learn.

This leads to what Boyle considered a crucial goal of constructivism – metacognition. Reflecting on the learning process allows the student to re-examine the nature of the problem and the varying approaches to its solution. This, in turn, can transform the way in which the student thinks (Cunningham, 1991, in Boyle, 2000, online).

Constructivism perceives knowledge as a continually evolving entity. The concepts we develop are evolved from past and present experiences, aimed at increasing our understanding of our world. When alternative concepts challenge our beliefs we use the experience to modify our knowledge rather than abandoning it. With this in mind, constructivism can be seen as addressing conceptual knowledge. Constructivism does not reject lower levels such as rote learning; these are accepted as necessary but they are not a focal point.

The behaviourist/constructivist stances outlined in Table 3.3 show the extreme ends of a continuum. Ernest (1995) suggested that there is a linear pathway between these extremes, progressing through different phases of constructivism. The more salient nodes on this continuum are shown in Figure 3.2.

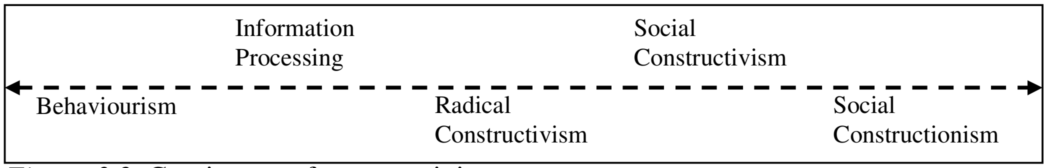


Figure 3.2. Continuum of constructivism.

These points are not discrete. There is no set of criteria that will precisely determine at which point a learning environment lies. The descriptions that follow outline the differences in pedagogy that will predominate at each stage, albeit characteristics from other phases will be present.

3.6.2 Behaviourism

Lakoff and Johnson (1980) described behaviourism as a view of the world in which everything is considered as a collection of unrelated objects and events without meaning. Meaning is created by joining together selections of these entities using rules of logic, irrespective of the values that could be brought to them from different perspectives. Consequently, the value of human imagination is significantly diminished. For this to hold true there would only be one interpretation of any given collection of facts. If we use the example of a red flag it is reasonable to assume that we all see the same object emitting energy waves that stimulate our retinas in the same way (genetic abnormalities notwithstanding). We may all see the same object but it will have different values in different contexts. The same flag moved to different settings could represent imminent danger (by the roadside), sporting allegiance (in a grandstand) or an individual's political persuasion (outside Parliament House). Global conflict indicates that more than one interpretation exists, which suggests that there must be something else influencing our thinking.

The 'traditional' view of knowledge does not allow any truth to be established for a single piece, or body, of knowledge. Knowledge can only exist within the reality perceived by the individual (Ernest, 1995). To establish a truth, the knowledge would have to be compared to the reality in which it is embedded, which cannot be achieved. However, this does not challenge our understanding of what knowledge is; it just means that knowledge cannot be proved. Constructivism, as described by von

Glasersfeld (1990), does not dispute this view; it abandons the paradox. Knowledge is seen to represent the potential to achieve within our own reality.

3.6.3 Information Processing

Kearsley described the information processing model by drawing on the earlier work of Miller (1956 & 1960, in Kearsley, 1996, online) and using an analogy of a modern computer. Perhaps Kearsley was buoyed by the eminent Russian computer scientist Andrei Ershov:

> Programmers constitute the first large group of men whose work brings them to those limits of human knowledge which are marked by algorithmically unsolvable problems and which touch upon deeply secret aspects of the human mind. (Ershov, 1972, in Lee, 1995, p. 284).

In a broad sense it is quite easy to consider human thought processing along the same input-process-output and storage lines as that of a computer. Data is input via the senses, undergoes various transformations within the cerebrum that results in some output, be it simply verbal or a more complex change in behaviour, and elements are held in memory. Galambos (1961, in Mikulas, 1974, p. 33) has even described the glia:brain relationship as analogous to that of the program:computer. Pribram (1961, in Swenson, 1992, online) believed that the internal processing took place in a linear series of events described in his Test - Operate - Test – Exit (TOTE) model.

Some input initiates a TOTE, testing the input against a preconceived standard. This testing may involve some operational mechanism to manage any arising conflicts between the new input and existing belief, often resulting in further testing. The Operate - Test will continue to iterate until the conflict is resolved, and the student exits the loop. Thus the TOTE model contains the three basic program structures of sequence, selection and iteration. People, like computers, will have selected data input to their processing system. Processing will pass through various stages before being ‘stored’ in memory or some output is achieved (Wilson & Myers, 1999).

An often over-looked problem with the brain:computer analogy is that humans have existed, in various forms, for at least two million years (Sarich & Wilson, 1967;

Dawkins, 2004), whereas electronic computers have only evolved over the last fifty years (Freed, 1995; Spencer, 1997). Computers were modelled on human information processing, not vice versa. Early attempts to replicate the ways in which humans performed did not work (Freed, 1995), leading to a very simplistic binary model for modern machines. The operational mechanisms inside the computer have been coded by humans. The analogy therefore implies that, at some stage, humans have been coded by other humans along behaviourist lines (Searle, c1990). However, information processing models do provide a primitive constructivist perspective. The input-process-output concept implies that we are not simply empty vessels into which knowledge is poured. The processing phase implies that we are, somehow, modifying data received from the environment according to our prior beliefs (Wilson & Myers, 1999).

3.6.4 Radical Constructivism

Ernst von Glasersfeld described a model of radical constructivism in which he claimed that, since all experiences are subjective, knowledge must also be subjective, as is the interpretation of that knowledge (Wilson & Liepolt, 2004). Von Glasersfeld summarised this position by quoting the 18th century philosopher, Giambattista Vico: "God alone can know the *real* world, because He knows how and of what He has created it. In contrast, the human knower can know only what the human knower has constructed" (von Glasersfeld, 1989, p. 123). Knowledge is recognised as a process of the brain; it is not meant to reflect a true image of the world, as truth is dependent on the viewpoint of the individual. Radical constructivism suggests that individual knowledge represents an internal organisation of the world experience by the individual (Tobin & Tippins, 1993).

Mortimer (1995, in Eskilsson & Helldën, 2003, online) suggested that students, as individuals, use different ways of thinking in different domains. Whilst studying students who were learning about *matter*, Mortimer identified three domains: *Sensible zone* (that which appeals to the senses); *substantialist zone* (students perceive matter as grains that can change state); and the *conceptual zone (*the conventional view of atoms as basic units of matter). Collectively these zones constitute a student's learning profile. Mortimer believed that students need to attain a concept within the conceptual zone and be able to reflect on their own. Aikenhead (2000) and Driver, Asoko, Leach, Mortimer and Scott (1994) were of the opinion that a student's conceptual profile will change as they learn about a given scientific concept. This focuses on the individual construction of knowledge rather than social construction. While it could be argued that this is a precursor to social construction of knowledge, radical constructivism does not need to go any further. One could develop knowledge by applying higher order thinking skills to existing knowledge without social interaction.

Driver, et al., (1994) pointed out that students' knowledge is not peculiar to the individual student. They reported modelling practices and methods of data interpretation that are common amongst different students, be they from the same or different cultures. Independent learning entails the use of symbols and methods of inquiry developed from within social domains (Linn & Burbules, 1993). Constructivism is viewed as a dialogic process in which students develop knowledge through social interactions. However, this does require students to undergo episodes of internalisation.

3.6.5 Social Constructivism

Solomon (1993b) raised three questions with regards to individual constructivism. If students are capable of constructing knowledge individually and in a logical, structured manner, why do they have difficulty understanding the logical methods of science, resulting in the perpetuation of their misconceptions? Again, if they have independently developed logically structured knowledge, why is this knowledge inconsistently applied in their lives? And why are their discrete sets of knowledge so comparable to their peers?

The perception of social constructivists is that all knowledge in constructed by the socialisation of individuals (Ernest, 1995). Sing (1999) argued that socialisation allows individuals to experience cognitive conflict, and therefore also experience the confirmation or modification of existing beliefs. Discussion between students provides all of those involved in the discourse with a scaffold on which their individual thinking can be developed (Driver, et al., 1994). It also helps students to restructure their thoughts through talking and listening.

The individual zones described by Mortimer (1995, in Eskilsson & Helldën, 2003, online) can be expanded through social constructivism. Vygotsky has defined the zone of proximal learning, in which students can solve problems and develop knowledge beyond their present intellectual level (Wilson & Liepolt, 2004). Development takes place within this zone, within the students' potential, when socialising with more proficient peers. Vygotsky (1962, in Huitt, 2000, online) proposed that during knowledge development, everything occurs twice. Initial socialisation leads to a metacognitive construction of knowledge. This internalisation leads to higher order thinking. The results of this process are incorporated into the social dimension. Ernest (1995) described this progression, in which social knowledge is placed above individual knowledge, as social constructionism.

At this point a caveat needs to be included. There is a danger in placing teaching-learning styles on a linear continuum, as shown in Figure 3.2. Western cultures read from left to right. Placing objects towards the right side of a continuum may result in the erroneous assumption that they are in some way better than those on the left. With regards to teaching-learning styles, the educational setting needs to be considered when determining the appropriate approach. It would be extremely risky to teach airline pilots how to fly jets purely by constructivist means; a behaviourist approach is also required. As an Army Reserve instructor 20 years ago, the weapons and field craft lessons that I conducted were almost exclusively behaviourist. Similarly, when I was taught how to destroy unexploded ordnance, the method employed was not discovery learning!

Applying this to a classroom context it should be realised that a teacher will choose the most appropriate approach from the continuum. Experimental research and design may well be via constructivist methods. Learning skills involved in connecting electrical circuits or using Bunsen burners would require a behaviourist approach.

3.6.6 Cultural Considerations

Cultural constructivism embraces the concept of social constructivism and further expands it. It includes cultural influences that will affect knowledge construction, including customs, religious beliefs and language (Dougiamas, 1998). Aikenhead (2000) suggested that social constructivism forces a particular culture (Western scientific) onto its minions. Therein arises a conflict; for students who do not embrace that culture, success at science will prove elusive whilst those already of a Western scientific persuasion have ‘got it made’.

Shutz and Luckman (1973, in Solomon, 1993b, p. 89) proposed that within socially constructed knowledge, objects are linguistically fixed. This raises two ideas. The development of language must have been a socially constructed phenomenon. Over a long period of time members of social groups have agreed about the meaning of every grunt we utter, and this allows us to develop understandings about whatever is being discussed. However, paradoxically we give our own meaning to these shared words (try telling a Year 9 boy he is wicked and watch his face grin; how do you interpret the sentence “The blackberries and blueberries are red because they are green”?), and so we will develop our own knowledge of the subject.

Aikenhead (2000) argued that we cannot expect students to adopt Western science to the exclusion of their prior beliefs. By combining cultural influences a better understanding can be achieved without replacing existing beliefs. This also enables a student to switch between cultures according to the environment in which they are placed.

Tobin and Tippins (1993) provided a different slant on constructivism as a referent tool, depending on whether the perspective of teaching/learning is that of the student or teacher. The teachers’ perspective has contrasting interpretations that seem to relate to the experience of the teachers. This view of constructivism as a referent needs to be expanded to include an analysis of the learning capability provided by the setting. Rather than focusing on what needs to be learned a teacher can improve the quality of the learning environment.

The basic principles of social constructivism can be summarised with two well-known quotes: “No man is an island” (Donne, 1624), and “All the world’s a stage…” (Shakespeare, c1599). A problem with describing the world as a stage full of actors is the possibility that it suggests a predetermined script. This would imply the passive reception of knowledge, whereas constructivist learning arises through social interaction, which can follow many paths. It would be better to consider the stage as being full of ad libbing actors, feeding off each other’s cues and allowing the play to develop.

Ernest (1995) described constructivism as a concentric structure, shown in Figure 3.3. Figure 3.3 depicts social constructivism as an interface between the socio-cultural context of science knowledge and personal constructions. Such a model negates any superior/inferior tag that might arise through a linear continuum of constructivist nodes; thus radical and social constructivism complement each other.

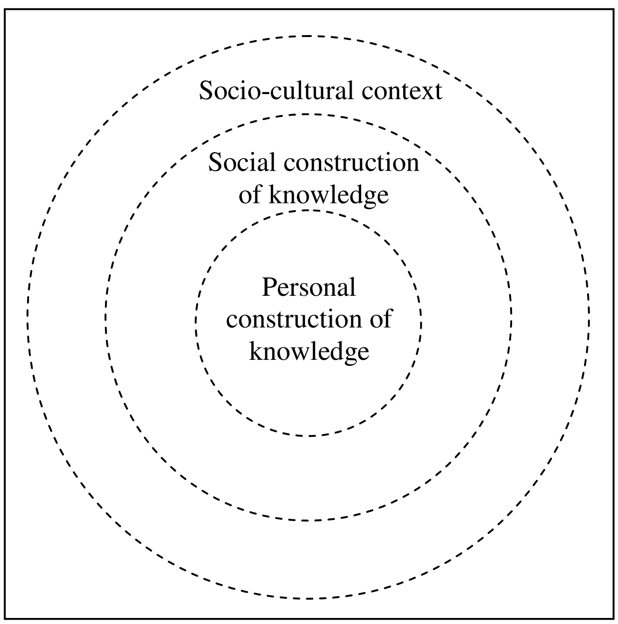


Figure 3.3. Constructivism in social perspective.

Coghlan (2002) stated that constructivism is essentially about helping people gain higher order thinking skills. This attainment has benefits that go well beyond the learning objectives of any course of study. The role of the teacher becomes a little clearer: Create the conditions under which social constructivism can develop.

3.7 BIOLOGICAL GENERATIVE LEARNING

Learning needs learners to engage three related sets of processes (Passey, 1999), internalisation, internal processes and externalisation. These sets allow data to enter the mind, undergo stages of processing that result in new knowledge, and return to the environment. These processes are shown in Figures 3.4 and 3.5. These diagrams summarises the *generative learning model* of Osborne and Wittrock (1983, in Featherstone and Hackling, 1997, p. 7); the *memory structure model* of Gagne and White (1978); and the *dismember-remember* model of Biggs and Moore (1993).

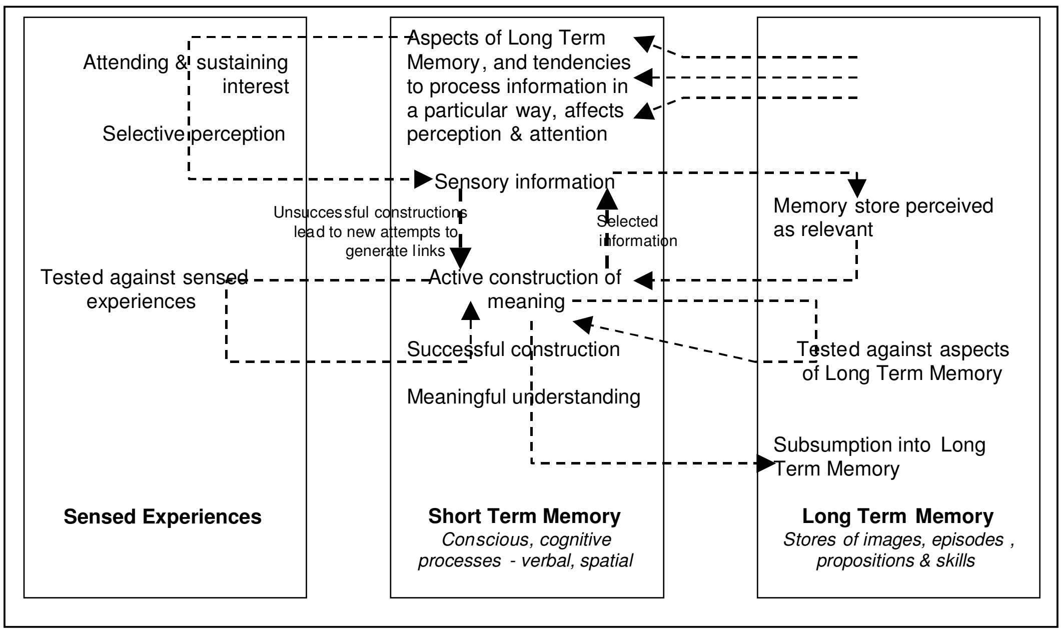


Figure 3.4. Generative learning model.

The generative learning component of shown in Figure 3.4 provides a constructivist view of learning. It clarifies how students construct meaning from their environment, by creating relationships between a currently studied subject and their previous conceptions about that subject. This construction of meaning, called learning, requires thinking, which is a function of memory (Wittrock, 1989). Scott, Asoko and Driver (1991) reminded us that, if new data conflicts with the beliefs already held by the student, the new data may be misinterpreted to reinforce the existing beliefs.

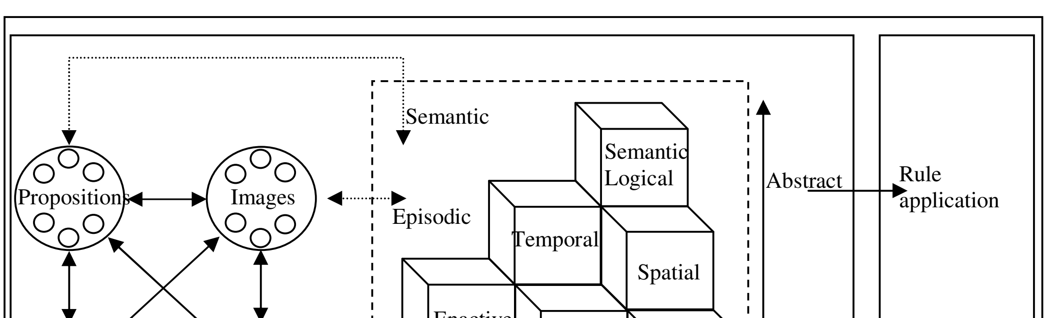


Figure 3.5. Dismember - remember memory model.

Figure 3.5 synthesises the work of Gagne and White (1978) and Biggs and Moore (1993). Within the long-term memory Gagne and White (1978, p. 195) have proposed the existence of four memory structures, based on measurable performances of their students in certain learning environments. The response, or performance outcome, can be classed as either knowledge stating or rule applying. Knowledge stating does not imply simple recall; it includes an understanding of the original meaning. Paraphrasing an essay, or painting a picture based on a poem, would indicate and understanding of the meaning of a topic. Rule application implies that a rule, once learned, can be transferred to a different situation; a concept expanded by the cognitive flexibility theory of Spiro (Spiro, Feltovich, Jacobson & Coulson, 1991) described in Section 3.8.

Biggs and Moore (1993, p. 221) presented a Piagetian array from procedural through episodic to semantic memory. The memory structures proposed by Gagne and White can contain the elements described by Biggs and Moore. These elements are stored separately, but not in isolation. They need to be recombined to demonstrate an understanding of a particular subject. The degree of success in this recombination (or remembering) is largely determined by how the initial data has been processed and stored. Parallels can be drawn between these memory structures and the non-connectionist models described in section 3.4.4.

3.8 COGNITIVE FLEXIBILITY

Cognitive flexibility is the capacity of an individual to restructure knowledge as required by changing situations (Spiro, et al., 1991). This theory has its origins in constructivism and allows for complex concepts to be examined without being simplified. Its focus is on learning within ill-structured topics (Swain, Greer & van Hover, 2001). Swindler (2001) described an ill-structured topic as one that requires the concurrent interaction of complex concepts.

Jacques and Zelazu (2005) have recognised two spheres of influence within the cognitive flexibility theory. The 'rule use', deductive domain is one in which sets of predetermined rules are applied to given structures, as depicted in Figure 3.5. The inductive domain requires students to approach a subject without a preconceived set of rules; the rules are selected and adapted by the students as the particular case demands. Jacques and Zelazu (2005) have described an overlap between the cognitive flexibility theory and the *theory of mind*.

The *theory of mind* explains how students' understand people as being constructs of mental beings (beliefs, desires, emotions, etc.) whose behaviours can be justified by considering these mental states. The variances in students' perceptions are partially explained by the cognitive flexibility theory. Students who are able to reason from more than one perspective are to perform better at abstract thinking tasks, due to their ability to understand how different positions can influence the solution to a given problem.

The application of technology to the contextual interpretation of text has been described by Jones and Spiro (1995). They suggest that it is possible to obtain higher levels of cognition by the use of computer systems, implying a convergence between the cognitive flexibility theory and ICT.

A traditional approach to teaching presents a hierarchy of knowledge around a central concept. This inhibits the development of higher understandings that could allow a wider application of the original concept; knowledge is applied in a restricted manner (Jones & Spiro, 1995). The cognitive flexibility theory opposes this view, allowing for the transfer of knowledge between ill-structured domains. According to the cognitive flexibility theory, the storage of data in a computer system, and the associated random access to this data, presents an ideal medium for the reorganisation of data. It becomes possible to approach thinking and learning based on a pliable, context specific arrangement of knowledge, rather than applying predetermined, memorised rules.

De Villiers (2002) recognised four principles that underlie the cognitive flexibility theory. Students should be presented with specific content within different contexts, and these presentations should not over-simplify the content. By supporting context-dependent content the teaching/learning environment emphasises the construction of knowledge. With regards to the concurrent interaction of complex ideas it is necessary for the learning contexts to be integrated, cutting across the traditional compartmentalisation of subjects within a high school timetable.

The manner in which students are taught has a major effect on the cognitive structures that they create; their knowledge structures and memory stores will influence the flexibility with which they can use their knowledge (Boger-Mehall, 1997). The prudent use of modern technology as described by Jonassen (1996) can be of great assistance in achieving this goal.

3.9 SUMMARY

Thinking is an active process. It requires some form of interaction with the external environment, which in turn is processed internally. This internalisation involves comparing new knowledge to that which is already held by the student. The exact mechanism by which this processing takes place is not fully understood, as implied by the fours models presented in this chapter.

It seems to be reasonably clear that thinking requires socialisation (Ernest, 1995). Thinking that leads to knowledge results from the critical discussion and analysis through the interaction with others in the environment (Driver, et al., 1994). The genetic differences between individuals, coupled with the different cultural perspectives of individuals, mean that our views of the world will differ from that of others. There can be no single ‘correct’ interpretation of environmental data (von Glasersfeld, 1989). Higher order thinking involves the integration of different knowledge sources and processing the data in original ways to create new knowledge. Chapter Four examines the role of computers as a potential aid in developing higher order thinking skills.

CHAPTER 4

IMPLICATIONS FOR INTEGRATING ICT WITH TEACHING AND LEARNING

4.1 INTRODUCTION

When used within a learning environment that endorses the cognitive flexibility theory of Spiro (1991), information and communications technology (ICT) allows students to integrate concepts from seemingly unrelated parts of the curriculum (Swain, Greer, & van Hover 2001). This would satisfy the concerns of Scott (1998) in Chapter One, who stated that classroom practices must change in order for computer technology to be efficiently implemented. Teachers will need to become facilitators of learning rather than authoritative figures. Concurrently, students will need to change from being passive recipients to active constructors of knowledge. Leamnson and Betz (1999) described emerging technology as an evolutionary process. As technology develops, they argue that it should take advantage of the biological models of learning earlier described. This would also permit the use of technology to focus on conceptual learning rather than students being besotted with the software.

4.2 TECHNOLOGY AS A COGNITIVE TOOL

Research conducted by Allegra, Chifari and Ottavino (2001) showed that the predilection of learning environments to incorporate technology can stimulate students to improve their divergent production, indicative of creative thinking. Solomon (1993a) considered technology to fall into one of two groups of cognitive tools. One group allows the more efficient processing of lower-order activities, thus allowing the user to focus on higher-order thinking pursuits – the second group. Milheim (1995) maintained that this grouping works because of five factors: Immediate response; non-linear access to data; adaptability of software; interactivity with the software; and self-pacing by the student. The groups do not mutually exclude each other. Those who wish to utilise ICT must attain a level of software proficiency. At a very basic level, a computer cannot help a student or teacher if neither has the skills to operate it. The degree to which it may be useful in addressing higher order activities will be determined by the range, and level, of technological skills.

This classification of software parallels that of Atkins (1993, in Harper, Squires, & McDougall, 2000 online). When reviewing the applications of multimedia to theories of learning, Atkins categorised software according to it fundamental standpoint of learning, either behavioural or cognitive. Atkins reported a change from software based on behavioural psychology towards a more constructivist approach.

Bricknell, Harper and Ferry (2002) argued that it is necessary to produce broad-based software that encourages students to comprehend and resolve problems that span different knowledge domains. This argument appears to be at a tangent to that of Solomon (1993a), Atkins (1993) and Jonassen (1996), who advocated the use of existing software. The contention of Bricknell, Harper and Ferry (2002) should take into consideration the fact that these authors also manufacture the type of software that they claim schools need.

This two-level model of technology is further developed by Jonassen (1996). Jonassen described the lower-order activities as being met by computer programs that he refers to as productivity tools. The higher-order activities are addressed by software referred to as mindtools. Jonassen tends to classify applications packages into one of these two groups based on the generalised nature of the software. Kim and Reeves (2004) suggested that classification of software should be dependent on the purpose for which the software is used. By this means, any computer program could be considered a productivity tool or a mindtool when used as such. A relational database, for example, can be a low-level catalogue of a set of music CDs, used to make the selection and location of a particular track easier to manage. Alternatively, it could be used to generate knowledge in a manner described by Maor and Phillips (1996): Databases, when used in a constructivist learning environment, enhanced the social interaction of students and created an environment in which higher order thinking skills could be developed.

Coley, Cradler and Engel (1997), when studying disadvantaged students, explained how these students have combined computers, drama and Socratic dialogue to develop their thinking skills. Students with some software experience were able to develop the learning opportunities of their peers, by means of in-depth questioning. Measures of these students' reading, writing, cognitive flexibility and metacognition demonstrates increased levels of performance.

Jonassen (1996) did not consider word-processing to be a mindtool, regarding it more as a glorified typewriter. However, in the same way that a spreadsheet can be used at two levels (a simple desktop calculator or a mindtool), so can a word-processor. Allegra, Chifari and Ottavino (2001) described how word-processing activities have enhanced student thinking about the structure of text, and increased collaboration between students when discussing texts. Specifically, the development of logical and linguistic skills was noted, accompanied by creative approaches towards problem solving. This overlayed the maturation of the students' social skills. Similar results have also been reported by Sherry and Jesse (2000). When working with students from low socio-economic areas they reported an increased awareness of the students with regards to their own learning; the students were developing metacognition.

The application of computer programs as mindtools supports a constructivist learning environment, as students are learning with computers and not from them (Jonassen, Carr & Yueh, 1998). Stoney and Oliver (1999) have demonstrated that, by using well designed interactive software, students become cognitively engaged, which leads to higher order thinking. It is important to note that the software they used was written for a specific university business course. The program *Principles of Financial Investment* (Stoney & Oliver, 1999, online) was designed to teach students about investing and share valuation. Tailor-made software tends to be expensive and has limited applications. Schools that have to adhere to strict budgets are more likely to rely on generalised software packages.

4.3 COMPUTERS IN THE LEARNING ENVIRONMENT

Passig (2001) contended that schooling needs to develop a different approach to developing cognition, based on predicted changes to society resulting from innovations in technology. These predictions are reinforced by Huitt (1995), who demonstrated the historical changes in our economic frame in Figure 4.1. Information as an industry has grown from around 3% in 1860 to greater than 50% in 1990. Passig warned us that, although these rapid changes are taking place, the approaches to implementing ICT in education have made little difference to students' cognitive skills.

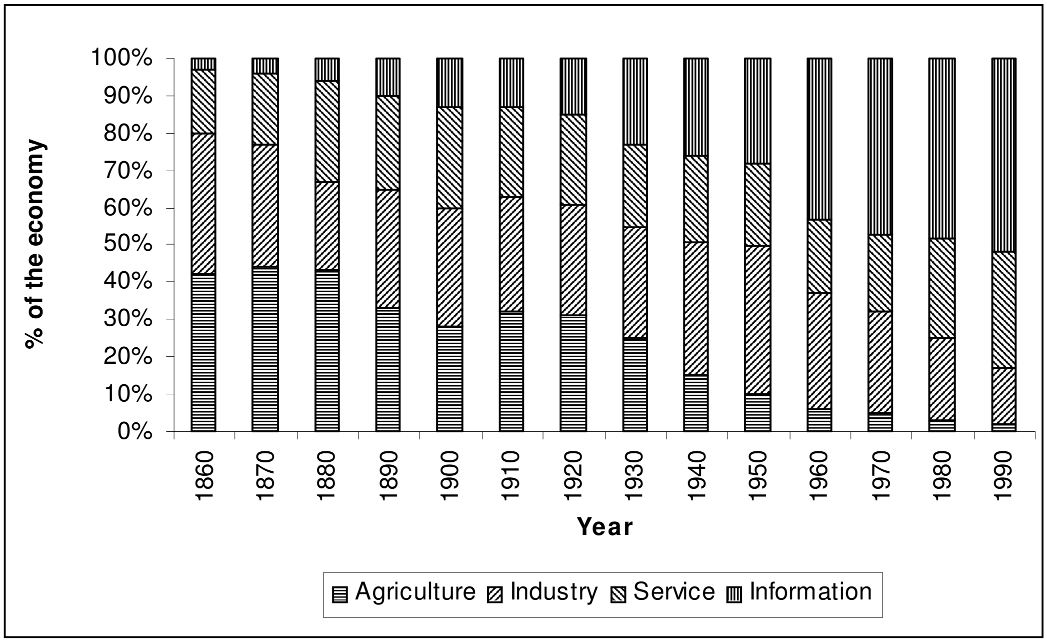


Figure 4.1. Historical changes in our economic climate.

Burbules and Linn (1991, in Maor & Phillips, 1996 online) have earlier agued that one of the goals of science education is to help students to develop their thinking skills in order to generate the ability to generate meaningful questions that can be investigated. Maor and Phillips pointed out that, while computers and associated technology have the ability to support this goal, there is little evidence to show that this has happened. This problem is partly explained by van der Straeten and Biesta (1999). In their treatise they stated the popular belief that schools are responsible for the transmission of knowledge to students. This demonstrates society's lack of understanding of the role of schools. Paradoxically they pointed out that schools are often criticised for dispensing lower order knowledge. The criticism arises from disjointed learning procedures in schools that are necessary if a lot of low-level knowledge is to be shovelled into students; more-or-less a self-fulfilling prophecy. Stoney and Oliver (1999) added to this argument, suggesting that one possible reason for the shortcomings of multimedia applied to student learning is the structure of the software. Many programs focus on one or two teaching objectives, for example the business course software used by Stoney and Oliver (1999), referred to in Section 4.2, and provide data in a strictly controlled linear sequence. This style of computer program is designed around a traditional teacher-led paradigm, which does little to enhance learning (Harper, Squires & McDougal, 2000).

Oppenheimer (1997) supported the claim that little academic improvement has been noted since the introduction of computers into schools. Furthermore, he claimed that stakeholders, with an interest in perpetuating ICT in the classroom, produce research that demonstrated academic improvements where no improvements have occurred. An example of this paradox is provided by Stevenson (1999) when evaluating the effectiveness of a laptop computer program in a school district. Students and teachers were surveyed over a three-year trial period. Data from the surveys are shown in Tables 4.1 and 4.2.

Table 4.1

Computer Activities in the First and Third Year of the Trial

	Use of the computer at least weekly (%)	
Type of Activity	1st Year	3rd Year
Taking Class Notes	83	81
Homework Assignments	70	81
Writing	51	52
Electronic Learning Activities	51	14
Accessing the Internet	45	38
Cooperative Learning	36	29
Student Research	26	25
Student Presentations	19	14

The data in Table 4.1 shows that activities such as note taking and writing have not changed over the three years, whilst activities such as electronic learning, cooperative learning and student use have all decreased.

Table 4.2

Subjects Utilising Computers in the First and Third Year of the Trial

Subject	Students using laptop at least weekly (%) 1st Year	3rd Year
English	66	47
Mathematics	25	11
Science	61	35
Social Studies	64	36
Other (Art, Music, etc.)	22	11

Table 4.2 shows that computer use across the core subjects has decreased, and yet this report concluded that:

> Teachers indicated that the laptop project generally had been satisfactorily implemented…
> …A majority of teachers, regardless of years with the laptop project, rated the overall impact of the laptop program on learning as positive…
> …Student and teacher attitudes continue to be positive regarding the impact of the laptop computer project…
> …Use of the laptop computers as notebooks continues to be associated with sustained level of academic achievement over time… (Stevenson, 1999, online)

Clearly, these conclusions are not supported by the data. Concurrent with the stance taken by van der Straeten and Biesta (1999), Dimock and Boethel (1999) reported that technology is able to provide greater resources for students with respect to problem solving, thinking skills and metacognitive activities. However, they pointed out that this claim, and similar claims, remain largely untested. They recommended that the relationship between technology and constructivist learning environments be further investigated.

When verbalising their thoughts, and reflecting on those thoughts, students have been shown to realise that they were taking an active role in their learning (Maor & Phillips, 1996). Laurillard, (1993, in Maor & Phillips, 1996 online) has suggested that this could be a shortcoming of computer-mediated learning. There is no discussion or reflection between the student and the computer. Neither can the computer intelligently analyse student's input; the interpretation is based on preconceived, human inputs. To accept that this argument is valid is to admit a poor understanding of the role of the computer. Kim and Reeves (2004) claimed that this argument has arisen, and is maintained, by regarding computers in education within a preconceived framework. Rather alarmingly Lee (2002a) reported that the main use of ICT, in subjects as diverse as Chinese and mathematics, is still predominantly used to collect facts rather than promote higher order thinking. The move from quill to slate, blackboard, whiteboard and computer has seen little change in pedagogy. This reticence is due, in part, to the notion that computers may one day replace teachers. While still given credence, albeit by those with little pedagogical experience, it brings to mind a relevant statement by Thornburg (1999, online): "Any teacher that can be replaced by a computer, deserves to be."

Learning environments that are based on inter-student communications provide a stimulus for invoking higher order thinking skills. This is brought about by students having their personal analyses and evaluations challenged by their peers (Gokhale, 1995, and Ferry, Kiggins, Hoban, & Lockyer, 2000). Maor and Taylor (1993) proposed that it is the supportive role of the teacher that facilitates students' use of the computer as a learning tool. Of equal importance is the role of the teacher in providing constructive criticism to further develop learning (Maor & Phillips, 1996). This belief is supported by Matthews (2002) and Thomas (2002). When researching online and face-to-face teaching methods both Matthews and Thomas reported that a hybrid model, consisting of both online and face-to-face modules, were most successful when the face-to-face module promoted higher order thinking related to the online content.

As discussed in Chapter Two, a vital element in the development of higher order thinking is the reflection of the learning experience by the student, which allows the new knowledge to be integrated with that in pre-existence. Laurillard (1995, in Stoney & Oliver, 1999, online) pointed out that student reflection usually takes place in solitude, without the teacher's knowledge. Certainly, many students are required to keep a reflective journal, yet many are guilty of following "Fatima's rules" (Aikenhead, 2000, pp. 247-248), named after a rather forthright student. Aikenhead (2000) described the situation in which, when faced with the knowledge that their reflective journals constitute part of their assessment, students will often record what they believe their teacher wants them to have learned, irrespective of whether or not the learning has occurred.

Maor and Fraser (1999) have demonstrated that interacting with a computer database improves student’s inquiry skills. The concerns raised by Laurillard, (1993, in Maor & Phillips, 1996 online) are addressed by embedding such activities in a constructivist learning environment. Such an environment allows greater opportunities for skills development such as developing hypotheses, interpreting graphical data and generating questions of a creative nature. Consequently, their higher order thinking skills are enhanced. Similarly, Allegra, Chifari and Ottavino, (2001) have shown that learning environments incorporating multimedia stimulate the divergent thinking of students.

4.4 SUMMARY

Chapter Two provides historical definitions of higher order thinking. Throughout these definitions there is a common theme; they all relate to the higher levels of cognition adopted by Bloom, et al., (1956) and reorganised by Anderson and Krathwohl (2001). Marzano (1988) and Burkhardt (2003) identify these higher orders of thinking as those skills that make up a student’s ability to think critically and creatively, which leads to the definition of higher order thinking skills adopted for this research: Those mental processes that allow students to develop factual, procedural, conceptual and metacognitive knowledge within the creative and critical domains.

Chapter Three describes the biological and socio-cultural theories that allow these thinking skills to take place. The continuous remodelling of dendritic associations within the brain and the social construction of ideas can both be considered as evolutionary processes. In this case the result is more sophisticated thought, rather than a new organism.

The main advantage of computer technology in the classroom is its function as a cognitive tool. The technology described in Chapter Four can be used to enhance the thinking processes. It allows faster manipulation of lower order, mechanical activities. This allows the student to quickly bring together a greater range of data, and manipulate in new ways to develop new knowledge (Jonassen, 1996).

Simply putting computers in a classroom will not lead to higher levels of thinking (Passig, 2001). Kim and Reeves (2004), and Lee (2002b), argued that developments in technology must be accompanied by changes in pedagogy; using new tools in old ways will not improve thinking. One approach is to promote a constructivist learning environment, rather than maintaining a traditional behaviourist style. Learning environments, as discussed in the succeeding chapter, have considerable influence on students' thinking.

The success of technology, with respect to enhancing higher order thinking, has been the subject of debate for the past two decades. As schools move towards more constructivist pedagogies, the impact of technology needs to be revisited. The following chapters review methods of analysing the learning environment, measuring critical and creative thinking, and determining the impact of technology on these factors.

CHAPTER 5

LEARNING ENVIRONMENTS

5.1 INTRODUCTION

It has been calculated that, by the time they have finished their compulsory years of school, students in Australia have spent 15,000 hours in the classroom (Fraser, 1998a). The classroom environments in which they learn have a strong influence on the outcomes of that learning (Fraser, 2001). In the interests of improving student outcomes, these learning environments need to be studied.

The classroom environments can be described from the perspectives of the participants; the teachers and students (Fraser, 2000). This approach may provide data that would otherwise be considered insignificant by an impartial, external observer. Fifteen thousand hours at school allows students to experience many classroom environments and have enough exposure in those settings to form qualified opinions about the learning environments.

Students' and teachers' perceptions of the learning environment can be compared with that of an external observer and with systematic recordings of observed events within the classroom. This follows directly from the work of Murray (1938, in Fraser, 1998a, p. 528) who introduced the terms alpha press and beta press to describe the environment measured externally or internally, respectively. These expressions were developed from the formula of Lewin (1936, in Fraser, 1998a, p. 529)

$$B = f(P,E) \quad \text{where } \begin{array}{l} B = \text{Behaviour} \\ P = \text{Personality} \\ E = \text{Environment} \end{array}$$

to represent the personal and environmental elements in common terms. Fraser cited the earlier work of Stern, Stein and Bloom (1956, in Fraser, 1998a, pp. 529-530) in which the beta press is sub-divided into the private beta press and consensual beta press. These divisions represent the views of individual students with regards to their environment, and the view of the peer group. The beta views can differ from each other and differ from the alpha view. This has two important ramifications.

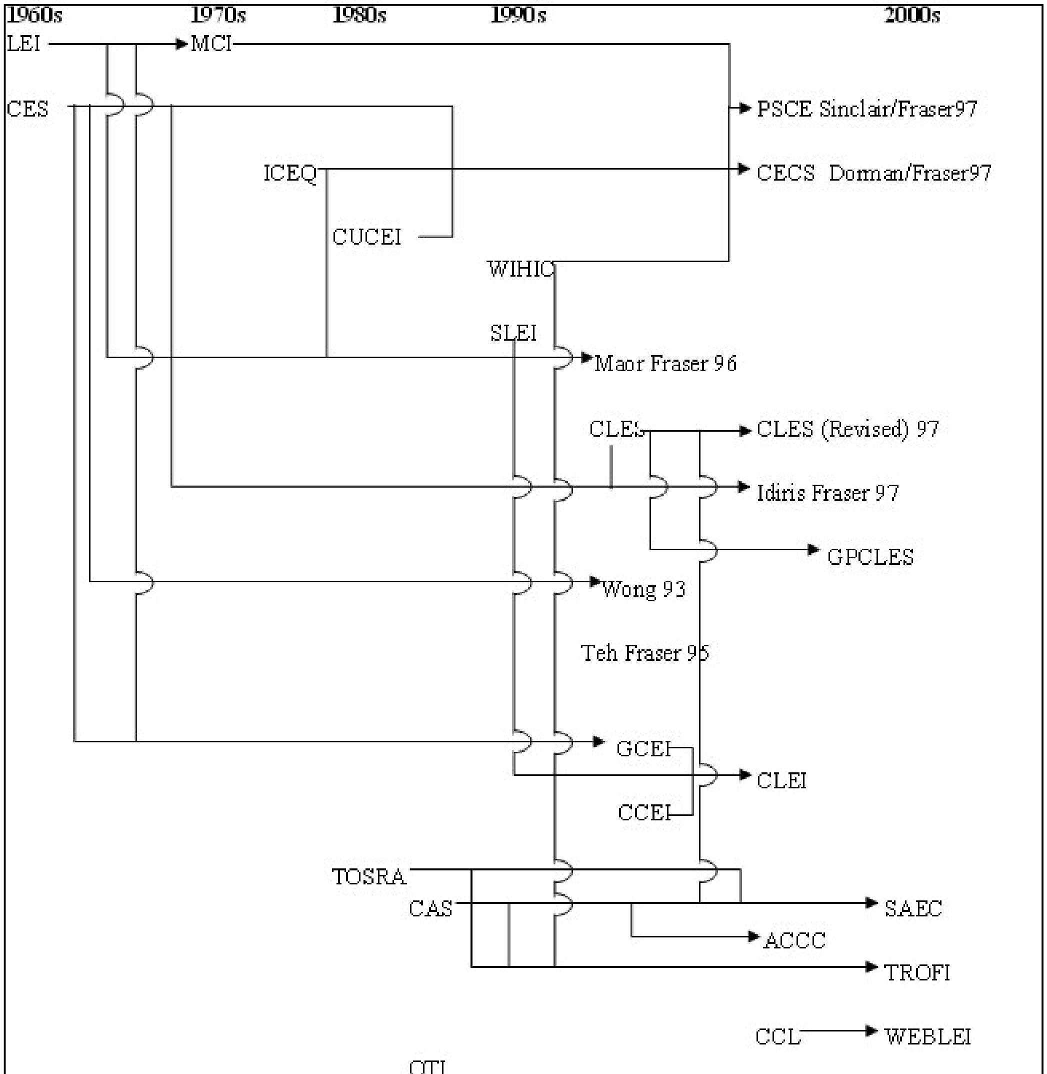
First, the classroom environment cannot be considered the same as the school environment. Different classes will invoke different responses from the same students, whether this is in response to individual ability or success at a given subject, or their relationship with different teachers. Additionally, the school ethos may contain elements not considered in individual classes (Fraser, 1998a). The success or failure of school sporting teams, the school community's stance on uniforms, or even the quality of the canteen food, may be important at the school level yet have little meaning in a science class. Any study of a learning environment, therefore, must clearly state the level at which the environment is being studied.

Second, the choice of the unit of analysis needs to be considered. If individual private beta presses differ from the consensual beta press, should the unit of analysis be the individual student perceptions or that of the peer group? Fraser (1998a) stated that analysis of relationships at one level can differ significantly from analysis at another level. If data collected from individual students are used to determine a student view of the learning environment it could produce quite different results to data collected from the student body.

5.2 LEARNING ENVIRONMENT INSTRUMENTS

A useful research tool for collecting data about the learning environment is the questionnaire. Many questionnaires have been developed over the last few decades; for example, the *Learning Environment Inventory* (LEI; Fraser, 1998a), *Classroom Environment Scale* (CES; Fraser, 1998b) and *My Classroom Inventory* (MCI; Chang & Fisher, 2003). These can be used to collect data from either individuals or groups, and data related to whole school or classroom learning environments. The validity and reliability of many of these scales is well documented (Fraser, 1998b; Newby & Fisher, 1997a). The consistently high internal reliability of these instruments should not be unexpected: Many of the more recent questionnaires, such as the *Constructivist Learning Environment Survey* (CLES) and the Computer Laboratory

Environment Inventory (CLEI), are developed from earlier instruments such as the LEI. The evolutionary relationship between the more pertinent instruments is shown in Figure 5.1.



ACCC	Attitude towards Computers and Computer Classes	ICEQ	Individualised Classroom Environment Questionnaire
CAS	Computer Attitude Scale	LEI	Learning Environment Inventory
CCEI	Computer Classroom Environment Inventory	MCI	My Classroom Inventory
CECS	Classroom Environment Catholic Schools	PSCE	Primary School Classroom Environment
CES	Classroom Environment Scale	QTI	Questionnaire on Teacher Interaction
CLES	Constructivist Learning Environment Survey	SAEC	Student Attitude and Efficacy Scale
CUCEI	College and University Classroom Environment Inventory	SLEI	Science Learning Environment Inventory
GCEI	Geography Classroom Environment Inventory	TOSRA	Test Of Science-Related Attributes
GPCLES	General Paper Constructivist Learning Environment Survey	TROFLI	Technology-Rich, Outcomes-Focused Learning Environment Inventory
		WIHIC	What Is Happening In this Classroom

Figure 5.1. Development of present day learning environment survey instruments.

These questionnaires are usually designed to elicit information about elements within the learning environment as classified by Moos (1974, in Fraser, 1998a, p. 530). Namely, the dimensions of relationship, personal development and system development. Many of the instruments have their origins in the LEI and/or CES. The influence that these original forms wield raises the question “Why are they not still used in their original form?” Fraser, McRobbie and Fisher (1996) argued that the early instruments elicit student perceptions of the whole class and not their personal views. If a student approaches a questionnaire by asking themselves “What is my class’ belief?” rather than “What is my belief?” then individual student perceptions are not revealed. Different responses between groups of students of different gender or ethnicity would be difficult to extract.

5.2.1 Learning Environment Inventory and My Classroom Inventory

The original LEI required students to address 105 statements based on 15 scales, and respond on a four-point scale (Fraser, 1998a); a daunting prospect. This situation was addressed by the development of the MCI described by Fraser in an earlier paper (Fraser, 1989). The MCI has a reduced number of statements (25) and a simplified yes/no response scale. Perhaps this is a case of over-simplification. An example of the survey form (Fraser, 1989, p. 3) shows a partially completed questionnaire. Many responses have been left unanswered, presumably to give clarity to the explanation of the questionnaire. However, no instructions are provided with regards to the treatment of blank responses from teachers or students. Some statements such as “Pupils are always fighting with each other” or “Only the smart pupils can do their work” contain the absolutes ‘always’ and ‘only’. These can invoke a yes/no response. Other items are not as clear. For example, “Pupils seem to like this class” or “Schoolwork is hard to do”.

From a teacher’s perspective the response to whether or not students like the class will vary depending on which pupils are being considered. In primary schools it is common practice for one teacher to teach many subjects. Again, the question of whether or not schoolwork is hard will depend on which subject is being considered. When faced with the dilemma of a yes/no response it is not uncommon for students to leave the question unanswered. From the scorer’s perspective it is not known whether a blank response indicates “I don’t know” or whether the item has simply been overlooked.

It should also be realised that classroom learning environments have undergone considerable change since the initial development of the LEI in the 1960s. Teacher-led instruction is giving way to student-centred construction (de Villiers, 2002). Research within these new learning environments required the development of new instruments.

5.2.2 Constructivist Learning Environment

Taylor, Dawson and Fraser (1995) have demonstrated that within constructivist learning environments there are socio-cultural limitations that inhibit the constructivist nature of the learning environment. In a later paper Taylor, Fraser and Fisher (1997) established that a traditional teacher-centred approach to learning can superficially assume a constructivist approach. While this may appease school administrators it does not change the pedagogy.

Taylor (1996) used the terms *cold reason* and *hard control* to describe these limitations. This conjures up images of distant, unfeeling, bitter forms of rational, logical thinking. In other words, something not very nice. Taylor is portraying a situation in which mathematics (for example) is seen as a concept outside of human nature; a system of rules to be reinforced by their application. Oliver Twist asking for more, and the discourse that followed, illustrates the meaning behind *hard control*. Mr Bumble represents the omnipotent teacher, measuring out precisely what is required to his students, irrespective of his students’ needs. The empty bowl, remaining empty, clutched in pleading hands depicts total subservience. *Hard control* delineates the situation in which the classroom is an environment of conflict. Students assume that they will be taught at, by a teacher enforcing order so that ‘learning’ will occur. Recombining the two myths produces a complex, recursive social state. The oblivious receipt of these myths by the students reinforces the belief that this environment is acceptable.

Tobin and Tippins (1993) remind us that a learning environment is not simply a place in which knowledge is transferred but is a cultural setting. This culture includes the cultural perspectives of the individual students. The students will construct their own learning environment by melding the classroom culture with their own. Recognising these integrated components allows us to construct a learning environment in which multiple forms of knowing are valued. Aikenhead (2000) argued that we cannot expect students to adopt Western science to the exclusion of their prior beliefs. By combining cultural influences a better understanding can be achieved without replacing existing beliefs. This also enables a student to switch between cultures according to the environment in which they are placed.

Taylor, Dawson and Fraser (1995) reasoned that in a classroom environment experiencing epistemological change, several learning environments can exist concurrently, and they can conflict with each other. Strategies designed to create learning environments that empower students may disadvantage students who feel more comfortable in a traditional, teacher-centred learning environment. These students tend to focus on the course content rather than engage in self-reflection.

Aikenhead (2000) suggested that we have to recognise that a constructivist approach is a sub-culture of the learning environment. This allows us to accept that there are other cultures at work in the classroom. These cultures need to be explicitly incorporated into a social constructivist environment, thus producing what Aikenhead refers to as a multi-science curriculum.

For example, several years ago when teaching in a low socioeconomic school I introduced aspects of Aboriginal science into a series of lessons on geology. It was quite fun making paint by grinding up rocks, and painting by making dots (rather than joining dots according to predetermined numbers). In addition, prints of *Bathers at Asnieres* (Seurat, 1884), a few outputs from a dot-matrix printer and newspaper photographs were left on the side benches, which led to a discussion on how different cultures can use the same tool in different ways.

Bentley (2003) stated that the purpose of critical constructivism is to bring about an increased personal and social consciousness in students, thus allowing them to develop their reality and not someone else's. Hewson (1992) described learning for conceptual change as an interaction between new and pre-existing concepts; the outcome of the interaction depends on the quality of the interaction. The cultural setting must allow a student to experience conceptual change. The student must have the conceptual profile that provides the context in which conceptual change will occur. These are student-focussed components. Cold reason/hard control are teacher-based. Therefore, in a cold reason/hard control environment conceptual change cannot occur. Cold reason/hard control assumes that knowledge is independent of the world and of human experience. Von Glasersfeld (1990) explained that our knowledge cannot have been derived from something beyond our sensory experiences as we would have no means by which to experience it. Knowledge cannot exist independent of context. Constructivism requires a significant change in the epistemology of teachers. Evaluating the degree to which constructivist principles are achieved led to the development of the CLES (Taylor & Fraser, 1991, in Taylor, Dawson & Fraser, 1995, online).

5.2.3 Constructivist Learning Environment Survey

Although the original CLES is based on the premise that students are constructors of their knowledge rather than passive absorbers, the instrument ignores the cultural perspective of the classroom environment described above. The modified CLES is designed to examine the socio-cultural constraints that allow this situation to perpetuate. Kim, Fisher, and Fraser (1999) reported that over the past two decades a number of instruments have been developed to assess aspects of classroom learning environments. They point out that these instruments are generally couched within a behaviourist framework, which may bring into doubt their validity within a constructivist classroom. Instruments designed for constructivist environments were found to focus on social constructivism (Taylor, Fraser, & White, 1994), ignoring other elements of the continuum shown in Figure 3.2 (Chapter Three). The incorporation of a *critical theory* perspective of the learning environment, the modified CLES should allow teachers to address these limitations.

Elements of the environment specifically examined by this instrument are the

- Relevance of the subject content to the students' real world;
- Students' control of the learning environment;
- Student-student interactions;
- Students' control of the learning activities; and
- Uncertainty of the subject content.

Borrowing a selection of questions from another instrument, and intermingling them with the existing questions, has addressed the attitudinal dimension, recommended by Maor & Taylor (1993).

The scales of the CLES were developed from the *critical constructivist* position (Taylor, 1994, in Taylor, Dawson & Fraser, 1995, online). Students' cognitive activity takes place within, and is limited by, their socio-cultural context. Samples of scale items within this instrument are shown in Table 5.1 (Taylor, Dawson & Fraser, 1995, online).

Table 5.1

CLES Scales and Sample Items Used in the Grade 10 Science Study

CLES Scales	Sample Items
	In this Biotechnology class. . .
Personal Relevance: relevance of learning to students' lives.	I learn about the world outside of school.
Critical Voice: legitimacy of expressing a critical opinion.	It's OK to ask the teacher "why do we have to learn this?"
Shared Control: participation in planning, conduct and assessment of learning.	I help the teacher to plan what I'm going to learn.
Uncertainty: provisional status of scientific knowledge.	I learn that the views of science have changed over time.
Student Negotiation: involvement with other students in assessing viability of new ideas.	I ask other students to explain their ideas.

The allocation of the questions to different scales of the instrument is shown in Table 5.2 (Taylor, Fraser & White, 1994, online). This raises another concern; the role of Question 29 and the disappearance of Question 36. Question 29 ("I feel confused") has been used to address both the elements of Student Negotiation and Attitude. The Attitude questions relate to various aspects of enjoyment of the subject whereas the

Student Negotiation questions relate to relationships with other students. The underscore indicates that, with regards to Attitude, the question is reversed scored, unlike its treatment for Student Negotiation. Question 29 “I feel confused” appears a little ambiguous. The Cronbach alpha coefficient for Student Negotiation (0.68). is acceptable. No such coefficient is provided for the Attitude element, and no data showing the contribution of each question towards the coefficient are provided. The reliability of the Attitude section is, therefore, questionable.

Table 5.2

Allocation of Items to CLES Scales

Scale	Item Numbers						
Personal Relevance	1	7	13	19	25	30	37
Mathematical Uncertainty	2	8	14	20	26	31	38
Critical Voice	3	9	15	21	27	32	39
Shared Control	4	10	16	22	28	33	40
Student Negotiation	5	11	17	23	29	34	41
Attitude	6	12	18	24	29	35	42

It is possible that the decision to include the attitude scale in the CLES was erroneous. The CLES was designed to measure elements of the learning environment. It could be argued that a student’s attitude is an attribute of the student applied to the environment, and is not a part of the environment. At the same time, the collective attitudes of students could be deemed an attribute of the environment from the perspective of an individual student. While determining students’ attitudes towards the learning environment is important (Maor & Taylor, 1993), it may be more appropriate to separate attitude about the environment from the measurement of the environment.

Question 36 (“I have a say in deciding what activities I do”) seems to belong in the division Shared Control, yet its allocation cannot be determined from Table 5.2. It is feasible that the concerns related to Questions 29 and 36 are simply due to typing errors in the original tabulated data. Some integrity is derived from the researchers discussing anomalous results with the participants during student interviews.

However, in the absence of any evidence, other researchers using this instrument would be advised to conduct their own reliability tests.

Designed to address issues of culture within a learning environment, the CLES has been adapted for use in other societies. Puacharearn and Fisher (2004) described a study that was conducted in Thailand. In this country classroom environments are predominantly teacher-led, with a lecture style approach. Although this is a well-established approach, the result is that Year 12 students are only able to pass one out of eight examined subjects, where a pass means greater than 50 per cent (Ministry of Education, 2000, in Puacharearn & Fisher, 2004, online).

Recent educational reforms within their educational system has seen a move towards cooperative learning within a constructivist basis. Applying the CLES instrument has shown that the learning environment, and students' perceptions of science, have developed. The research also demonstrated that the CLES may be successfully applied to other cultures.

Dorman, Adams, and Ferguson (2003) have stated that academic effectiveness is positively related to academic enthusiasm and academic performance, and conclude that the degree of academic efficacy predicts the degree of academic achievement. From this they argued that the quality of the learning environment is related to academic efficiency within that environment. A cross-cultural study of 3,602 mathematics students in Australia, England and Canada using a combined WIHIC and CLES instrument supported this argument and further validated the individual instruments. However, they also noted, via commonality analysis, that the CLES did not explicate the variance of academic efficiency beyond that accredited to the WIHIC scales.

5.2.4 Computer Laboratory Environment Inventory and the Attitude towards Computers and Computer Classes

Based on the SLEI, with elements of the GCEI (Teh & Fraser, 1994) and CCEI, the CLEI is designed to assess the learning environment of computer laboratories in tertiary institutions (Newby & Fisher, 1997b). Initially the SLEI was developed from existing survey instruments by identifying classroom dimensions considered unique to the science laboratory environment. Whilst the selected scales are important, the uniqueness of the science learning environment is not really addressed if, in fact, this uniqueness actually exists. ‘Student Cohesiveness’ is an important factor in many classroom environments, hence its retainment in the CLES. ‘Open Endedness’ and ‘Integration’ apply equally to Economics and Drama classes. ‘Material Environment’ can be used in any classroom environment that requires specialist equipment. For example, Metal Work, Home Economics or Physical Education. Similarly, ‘Rule Clarity’, which focuses on safety issues, can be applied to any class using specialist equipment with inherent risk factors.

Student achievement is promoted by classroom environments in which students perceive greater student cohesiveness, satisfaction and direction, accompanied by reduced disorganisation (Newby & Fisher, 1997b). The instigation of computers as a learning tool led to the modification of existing survey instruments to assess the learning environment within computer laboratories. Concurrent with the development of the CLEI was that of the ACCC, designed to assess the attitude of students towards computers and computer classes. This instrument is based on the principle that attitude has four elements – cognition, affection, behaviour and perceived behavioural control (Newby, 1998).

While attitude cannot be measured directly, these components can be measured, and from them the overall attitude can be inferred. Lee (1970, in Newby & Fisher, 1997a, p. 184) has described two relevant dimensions of attitude towards computers; the belief that computers are useful tools and the belief that computers can replace people. These dimensions are expanded into computer anxiety, enjoyment of computers and computer usefulness. The final ACCC instrument, based heavily on the *Computer Attitude Scale* (Loyd & Loyd, 1985, in Newby, 1998, p. 75), addresses the cognitive and affective domains. The elements pertaining to behaviour have been left out, primarily for reasons of economy.

Newby and Fisher (1997b) reported that while the CLEI is reliable it requires further modification to reduce overlap between its internal dimensions. As such, it should be possible to adapt the CLEI for use in secondary schools. Questions such as “I get on well with students in this laboratory class" and "The computer software runs without any problems" are valid in secondary school computer laboratories. In its present form the CLEI does not address Rule Clarity (present in the SLEI) on the basis that this is a behavioural rather than safety issue in a computer laboratory. The relevance of this dimension within a secondary computer environment will need to be determined by the individual researcher. Many schools are experimenting with the use of notebook computers by staff and/or students (Kessell, 2001). Effectively this makes every classroom a computer laboratory, which will require further editing of the CLEI instrument.

One use of the CLEI is to have students complete a survey based on their ideal perceptions and another based on their perceptions of the actual learning environment (Fisher, 2005). Differences between the survey results are used to modify the learning environment. Data plots for the original SLEI, and the new CLEI, are presented as line graphs. A typical graph is shown in Figure 5.2.

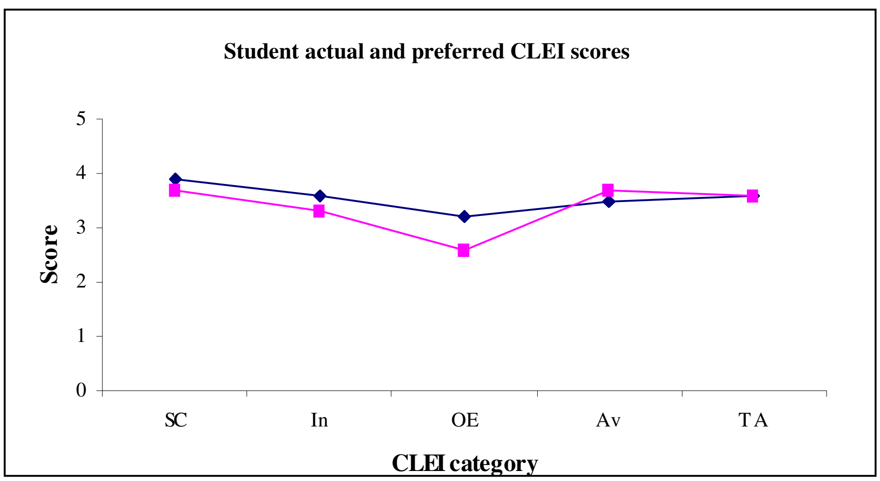


Figure 5.2. Original order of CLEI scales.

Line graphs are generally used to represent continuous data (Biology Department, 2004). The five categories of the CLEI and SLEI are discrete, meaning that there is no numerical relationship between the five points. Rearranging the order of the categories can produce the graphs shown in Figure 5.3 and 5.4.

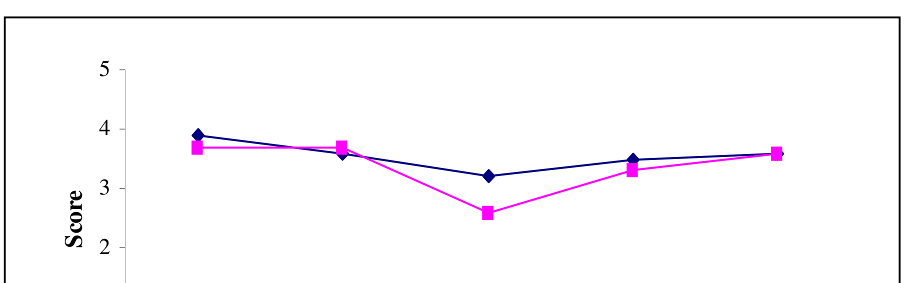


Figure 5.3. First rearrangement of CLEI scales.

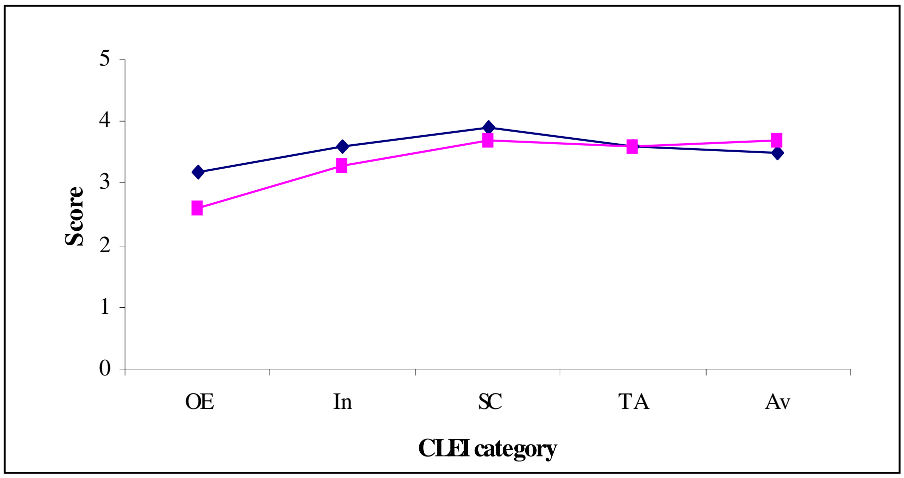


Figure 5.4. Second rearrangement of CLEI scales.

All three graphs show the same data yet the relationships inferred from the continuous lines are quite different. Humans read from left to right. When this behaviour is applied to a line graph the desire to recognise a pattern described in Chapter Three (Lowery, 1998) is activated. In this instance, relationships between the five discrete points appear, even though they do not exist.

A suggested alternative is to keep the data as discrete units and focus on the difference between data within each scale, as shown in Figure 5.5. The five scales on the x-axis in Figure 5.5 can be presented in any order. The emphasis remains on the differences between the responses to each scale.

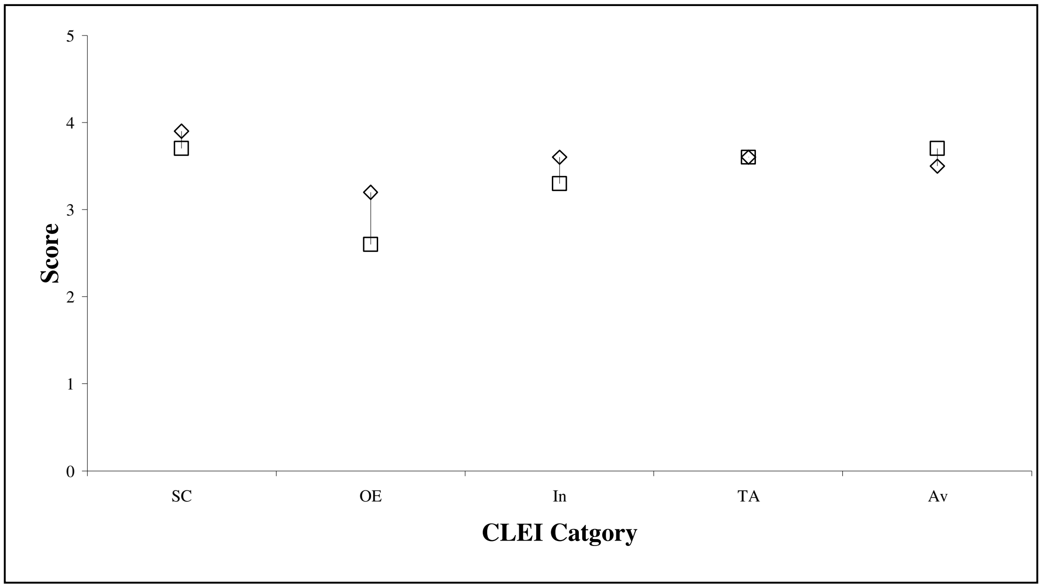


Figure 5.5. Discrete plotting of CLEI data.

5.2.5 Questionnaire on Teacher Interaction

Figure 5.1 shows that many of the present-day learning environment questionnaires have their origins in the LEI and CES. These original instruments were derived from the independent works of Moos and Walberg (Fraser, 1998a). While the present instruments measure various aspects of Moos' dimensions, none of them specifically address the teacher-student relationships within the learning environments. The QTI addresses this shortfall and, as will be demonstrated, may be used to provide a broad description of the degree of constructivist pedagogy being employed.

Initially developed by researchers in the Netherlands, the QTI is based on the work of Leary (1957, in Stolarchuk & Fisher, 1998, online). The dialogue between patients and therapists within various institutions were analysed by Leary, and reduced to a series of statements that represent different types of interpersonal behaviour (Lourdusamy & Khine, 2001).

Leary proposed an interpersonal theory made of three principles. The first principle states that a one-to-one relationship will evolve based on verbal and non-verbal cues that pass between the participants. These cues can be regarded as complementary – dominant/friendliness from one person encourages submissive/friendliness in the partner; dominant/unfriendliness will invoke a submissive/unfriendly response (Acton & Revelle, 1995).

Secondly, the principal of vector length allows a relationship between personality and social acceptance to be described. People who are flexible tend to have less social problems than those who are aggressive and/or stubborn. The third principle is that of circumplexion. When personality variables are measured there is a tendency for some of the variables to overlap.

The QTI maps teacher-student relationships across two attributes, dominance/submission and opposition/cooperation, based on groupings of Leary's statements (Lourdusamy & Khine, 2001). This results in eight scales, as shown in Figure 5.6 (Fisher, Fraser & Cresswell, 1995). The instrument was further developed in Australia and consists of 48 statements scored on a five-part Lichert scale (Fisher, Fraser & Cresswell, 1995).

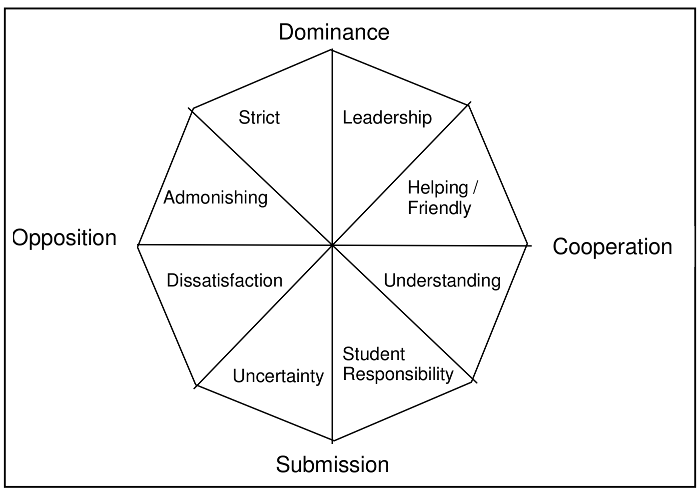


Figure 5.6. The model for interpersonal teacher behaviour.

Modification of the original instrument requires that it be validated. This particular model has been tested on numerous occasions summarised in Table 5.3. It can be concluded, from the statistical summary in Table 5.3, that the Australian instrument has a high level of internal consistency. Furthermore, its circumplex nature has been verified (Stolarchuk & Fisher, 1998).

Table 5.3

Validation Statistics for the Australian QTI Instrument

Researchers	Year	α-coefficients
Waldrip & Fisher	1995	0.80 - 0.95
Rickards & Fisher	1996	0.78 - 0.96
Fisher, Goh, Wong & Rickards	1996	0.76 - 0.84
Fisher & Rickards	1996	0.60 - 0.96
Stolarchuk & Fisher	1998	0.59 - 0.88

Fraser (2001) believed that the learning environment has a significant influence on student performance, and calls for increased research in this area. From a pragmatic view, there is only so much research to which a school can be subjected and there is a finite number of surveys that can be completed by students. Continued intrusion by researchers could change the dynamics being studied. The QTI has been used to generate learning environment typologies based on the teacher-student relationships (Fisher, Fraser & Cresswell, 1995). Fisher (2005) presented a range of QTI generated teacher-profiles that describe different learning environments in Australian schools, shown in Figure 5.7.

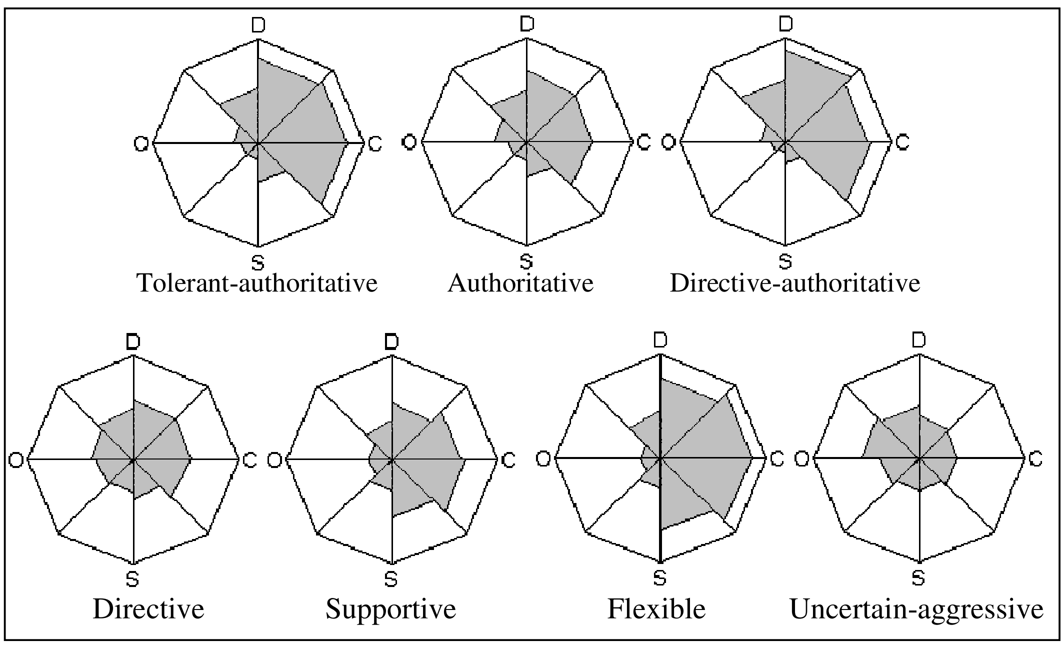


Figure 5.7. Australian classroom typologies as determined by the QTI.

Constructivist learning environments have been shown to coincide with the supportive and flexible QTI typologies (Fisher, 2005). In the interests of consolidating the numbers of surveys and classroom observations, the constructivist nature of the learning environment can be inferred from the QTI profile.

An earlier paper by Wubbels (1993) presented the QTI data as a line graph. This approach is repeated by Lourdusamy and Khine (2001). The circumplex nature of the eight scales supports the notion of continuity between two points either side of any given scale. Unfortunately, the line graph does not readily show the connection between the two extremes, as demonstrated in Figure 5.8.

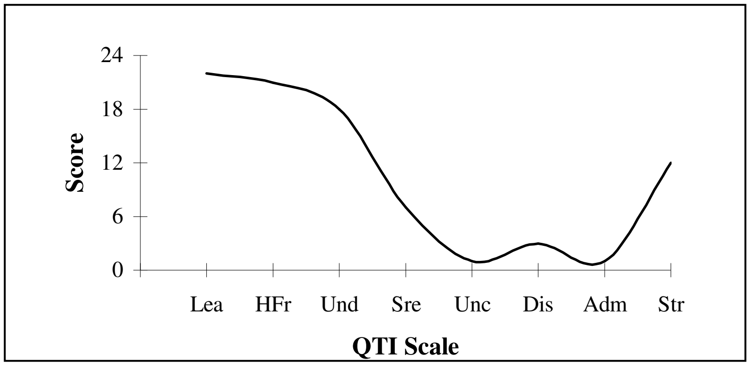


Figure 5.8. QTI scores show as a line graph.

While the sequence of scales must remain intact, the starting scale for the data (in this instance, Leadership) is arbitrary. A different graph is drawn if the initial scale is different. For example, a graph commencing with Uncertainty, as demonstrated in Figure 5.9.

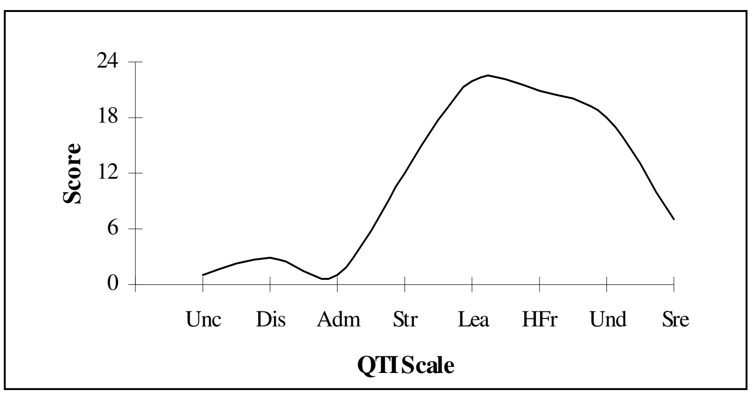


Figure 5.9. Rearranged QTI scores.

The data plots of Fisher, Fraser and Cresswell (1995); Fisher, Rickards and Fraser (1996); and Fisher (2005) can be described as radial column graphs. Each scale is treated as a separate entity emanating from a coaxial point. The same data shown in Figures 5.8 and 5.9 is redrawn in Figure 5.10.

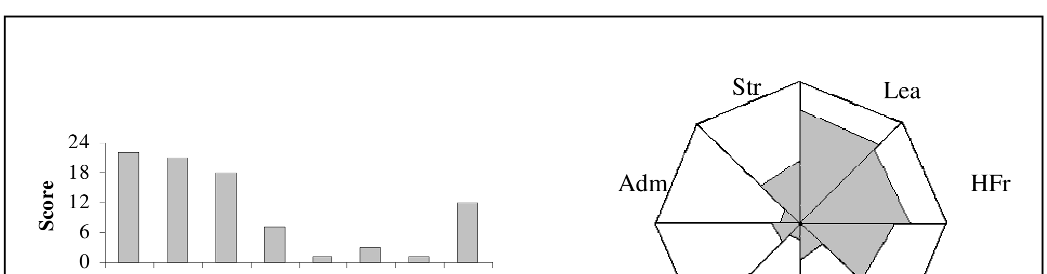


Figure 5.10. QTI scores shown as a radial column graph.

This radial column graph allows all of the scales to be seen relevant to their adjacent scales, and any erroneous inferences drawn from reading a line left to right are diminished. The jagged lines highlight that the radial graph has treated the data as discrete units, as in a standard column graph. This tends to hide the circumplex nature of the data. To overcome the deficiencies of the line and radial graphs, and concurrently build on their strengths, a third type of graph is proposed. An example is shown in Figure 5.11.

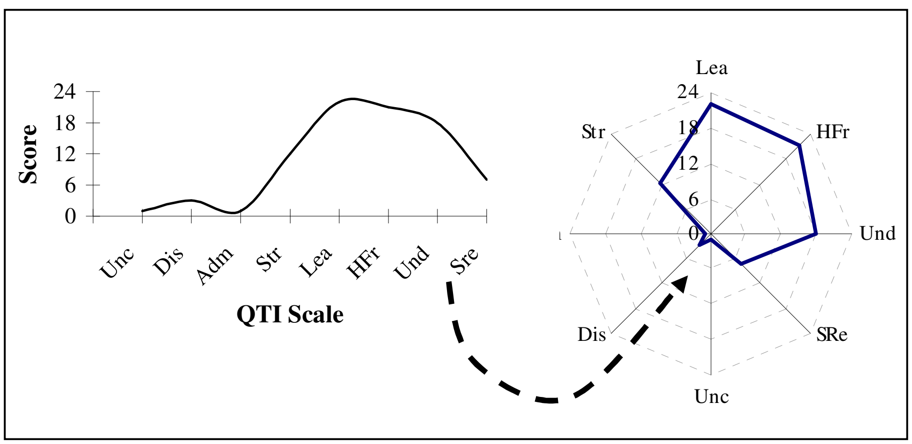


Figure 5.11. QTI scores shown as a radar plot.

The radar plot (Microsoft® Excel, 2000) shows the relationships between adjacent scales as a continuum, rather than discrete units. The relationship between Leadership and Strength, absent in Figure 5.6, becomes visible. This type of graph has an added advantage in that it can be easily reproduced using commercially available software.

Fisher (1986) described Moos' three dimensions of social climates: Relationship, Personal Relevance and System Maintenance. The QTI, whilst demonstrably reliable and valid, only provides a measure of the dimension of Relationship. Personal Relevance and System Maintenance are not considered. The CLES instrument does include Personal Relevance, so it may be inferred from the structure of the QTI graph. Both scales are measured by the CLEI and ACCC, which are usually administered as a single questionnaire.

5.3 TECHNOLOGY-RICH LEARNING ENVIRONMENTS

The MacQuarie Dictionary (2001) defines *technology* as a division of knowledge concerning the application of science and engineering, and *rich* as an abundance of desirable qualities (p. 1930; p. 1623). A search of the Internet revealed 786 references to technology-rich learning environments, with an assorted number of definitions, many idiosyncratic (Page & Brin, 2005). In the context of this thesis, a technology-rich learning environment refers to an environment that enables students to have sufficient access to computer-based technology to help their learning. It is an environment in which technology is considered transparent with regards to teaching and learning.

Gaynor and Fraser (2003) described two cases in which students embedded in a technology-rich environment were observed. While the focus of these studies was the online, portfolio-based approach of the teachers, the nature of the technology-rich environment was documented. This was achieved by observing the classes for two hours a week over seven weeks. It includes descriptions of the newly-acquired infrastructure as well as the students' activities, and is presented in an interpretive framework.

This bricoleur approach to research (Campbell 2002) allows the synthesis of whatever skills the investigator has, including "the aesthetic and material tools of his or her craft, deploying whatever strategies, methods, or empirical materials are at hand" (Greenwood & Levin, 2000, in Campbell, 2002, online). The derived degree of 'technology-richness' is somewhat dependent on the literary skills of the researcher and the inferences drawn by the reader. This will vary with different people, as will the interpretation of the prose. Certainly, the reader will conjure up a mental picture of the learning environment, but this needs some degree of quantification.

A similar study was conducted by Gay (2002), who investigated the changes in technology-use in the classroom in response to the creation of an online virtual learning environment. Gay used two questionnaires to examine the technology self-efficacy of teachers and the extent to which technology is used in the classroom. These questionnaires were based on the earlier works of Murphy, Coover, and Owens, and Phye (1989; 2000; in Gay, 2002, online). Two points need to be addressed in the study. The information provided by these questionnaires may not be collecting the data to which it purports. Responding to statements such as “I can use word processing software to write a letter” and “I can log onto the Internet” (Gay, 2002, online) only provides data related to lower order activities.

Secondly, while questionnaires can provide useful information, the questionnaires used by Gay were based solely on the self-assessment of those being studied. This needs to be reinforced by some form of objective assessment of technology skills and the classroom-based technology use. None of the statements in the first questionnaire relate to higher order cognition as described by Anderson and Krathwohl (2001). The second questionnaire only contains one statement that relates to teaching-learning with a computer: “How many times a week do you use a computer… for Internet research in support of your teaching?” (Gay, 2002, online), and it is not clear whether the use of the Internet is by the teacher or students.

Whilst examining the qualitative elements of a technology-rich environment, O’Dwyer, Russell, Beebell and Tucker-Seeley (2005) argued that traditional methods of assessing student performance may not be valid when technology is used. Existing instruments tend to measure critical and/or creative development in general terms, whereas technology is usually applied to specific learning areas (McNabb, et al., 1999; Russell, 2002; in O’Dwyer, Bebell, & Tucker-Seeley, 2005, online).

A similar argument was forwarded by McNabb, Valdez, Nowakowsk, and Hawkes (2004). In their study of the application of technology to the development of mathematics and science education, the use of standardised testing is criticised. Instruments such as the California Achievement Test and Illinois Measure of Annual Growth Exam do not evaluate higher order thinking or technology skills, or the context in which these skills are developed.

McNabb, et al., (2004) have developed a rubric that is used to assess students' portfolios. In doing so they indirectly measured the quality of the technology-use in the learning environment. Adapted from the WestEd Technology Implementation Assessment Rubric (Barnett 1998), this addresses criteria for

- Vision;
- Technology Needs;
- Technology Literacy;
- Curriculum Integration;
- Parental and Community Involvement; and
- Professional Development.

A significant element that is missing from this rubric relates to one of its original intentions – the assessment of students' higher order thinking. This omission highlights another concern of O'Dwyer, et al., (2005). When students within a specific environment are studied it is often with a purpose-designed instrument that has not been subjected to validation by a third party. In this case study, McNabb, et al. (2004), have modified an existing instrument yet have provided no data with regards to its validity or reliability.

The concerns raised by McNabb, et al. (2004), and O'Dwyer, et al. (2005), have been addressed by Moersch (1999). Identifying the need to link technology planning and use, and teacher professional development, Moersch developed the Level of Technology Implementation (LoTI) questionnaire. It is used to produce a teacher profile based on three domains: teacher pedagogy, personal computer use, and the degree to which technology is used in the classroom.

These domains are further divided to allow the assessment of teachers' technology confidence, competence and instructional practices based on six elements each at three levels. The results of the questionnaire, which includes classroom observations and quantification of technology implementation, determine the technology implementation of the teacher. Six levels are identified, each of which has a comprehensive description of the implied 'technology-richness' (Moersch, 1999).

Schechter (2000, in Moersch, 2001, p. 26) undertook research specifically to determine the reliability of LoTI when examining the integration of computers in the classroom. Cronbach's alpha coefficient shows an internal reliability of 0.75 - 0.81. When examining the impact of technology use on student achievement, Middleton (1999, in Moersch, 1999, p. 41), reported a significant correlation between teachers' LoTI levels and student performance in mathematics and reading.

Moersch has further explored the use of this instrument by examining three scenarios in which students undertook studies of a local environment, consumer science, and small business management (Moersch, 1998). However, in analysing the environments Moersch commented that the thinking skills have been used to determine technology integration, rather than technology being applied to help achieve higher cognition. Furthermore, the efficiency of technology integration does not appear to have been measured according to the LoTI criteria. Although the computers were undoubtedly used, and the pedagogy used was a sound, constructivist approach, the 'technology-richness' of the environments remains unknown. If the influence of technology on higher order thinking is to be determined, the instrument used to measure the quality of the technology must be used appropriately.

5.4 SUMMARY

Classroom environments can be described from the perceptions of the teachers and students within the class. These can then be compared with the classroom events recorded by an external observer, thus providing a deeper, contextual framework within which research may be conducted.

The plethora of questionnaires presented in Figure 5.1 may be drawn on to extract information about elements within the learning environment. As there may be several sub-cultures coexisting in one classroom (Taylor, Dawson, & Fraser, 1995), it may be necessary to use more than one questionnaire, each with its own cultural emphasis. One such sub-culture is that of technology-richness. A technology-rich learning environment refers to one that provides students with enough computer-based technology to help their learning.

The increased use of technology in the classroom becomes problematic; traditional methods of assessing student performance may not be valid when technology is used (O'Dwyer, et al., 2005). Moersch (1999) has developed an instrument that allows the level of technology implementation to be assessed, and thus provide an insight into this classroom sub-culture. When the various dimensions of the learning environment are identified, a contextually sound basis for the assessment of higher order thinking skills is created.

CHAPTER 6

ASSESSING HIGHER ORDER THINKING SKILLS

6.1 INTRODUCTION

Assessment has been defined by Chin, Munby, and Krugly-Smolska (1997) as the collection and interpretation of information, and the recommendations concerning the performance of individuals based on that information. In a secondary school, this information is gathered through activities ranging from simple classroom observations through to three-hour written examinations. Calloids (1996) raised the concern that there is a tendency for these assessment tasks to focus on recognition and recall of content relative to the learning area, rather than to address critical and creative thinking.

This chapter examines current trends in assessing and measuring critical and creative thinking. The advantages and disadvantages of various instruments are discussed.

6.2 APPROACHES TO THE ASSESSMENT OF THINKING

In Singapore, the ranking of students according to their scores in the General Certificate of Education (GCE) ‘O’ and ‘A’ levels is used to determine the degree of success of individual schools (Kim, 1996). This has resulted in teachers ‘teaching to the test’ with less emphasis on higher order thinking. Kim (1996) recommended adopting a system in which students’ performances are not compared with each other but are compared with descriptors of cognitive behaviour. At the time of writing (2005/6), it is possible to draw parallels between this argument and the controversy regarding outcomes based education in Western Australia. Many Western Australian parents, teacher-groups and individual teachers have grave concerns regarding this approach, specifically the nature of outcomes-based assessment (Berlach, 2004; Hiatt, 2005a, b; Stephens, Guise, Hames, Waldron, Whitely, Constable, & Hyde, 2005, Buggins, 2006, et al.; King, 2006). However, rather than creating sets of poorly worded, bland descriptors, Kim argued for the use of existing cognitive structures such as Bloom’s taxonomy (Bloom, et al., 1956) or Anderson’s revised taxonomy (Anderson & Krathwohl, 2001). Her belief that some knowledge tasks can be more complex than (for example) some analysis tasks, supports the adoption of Anderson's revised taxonomy described in Chapter Two.

Bradley (2005) maintained that critical thinking is fundamental to the curriculum and does not belong solely in any specific learning area. Concurrently, he argued that without being applied to a given context, learning higher order thinking skills is irrelevant. The inference is that students can be specifically taught thinking skills as a tool to be applied in any given context.

However, Carr (1990) argued that critical thinking courses could result in the fragmentation of thinking skills. Thinking is regarded as a means of learning content and should not be separated from it. Within specific contexts students should be taught how to critically analyse existing content and synthesise new ideas. One method proposed by Carr is to introduce the analysis of news media, where the media topic under review is specific to the course content. By providing alternative views of the same topic, students can be taught to be more critical and construct their own beliefs.

The Chicago Board of Education (2000) pointed out that a question intended to assess a higher level of thinking may, unintentionally, only assess thinking at lower levels. The determining factor is the previous exposure of the student to the content of the question. If a student has addressed the question during earlier lessons then they are simply recalling facts that they have already established. Preferably, a question should require students to generalise their understanding to the solution of new problems. This builds on the earlier findings of Kim (1996), who argued that, when marking a student's response to a question, it may not be possible to determine the student's level of thinking. A student's answer to an analytical question may simply be knowledge recall if the student has been exposed to many, similar questions. Kim (1996) suggested that a student's level of cognitive operation can be determined using Item Response Theory (IRT). This theory claims objectivity in measurement by separating test questions and individual's strengths. Separate scores are placed on a continuum that is determined from the correct answer, individual strengths and question parameters. Kim divided the responses into three categories, grouping together Bloom’s levels. Assuming a strict linear hierarchy, Kim recognised four possible response patterns, shown in Table 6.1.

Table 6.1

IRT Response Patterns

Response	1 Knowledge & Comprehension	2 Application	3 Analysis
1, 2 & 3 incorrect	0	0	0
1 correct, 2 & 3 incorrect	1	0	0
1 & 2 correct, 3 incorrect	1	1	0
1, 2 & 3 correct	1	1	1

The mean plot for ten such continua is shown in Figure 6.1 (Kim, 1996).

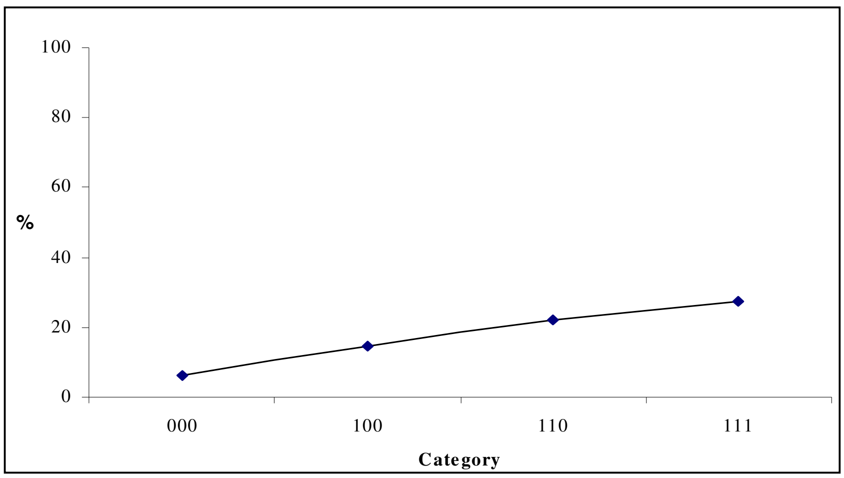


Figure 6.1. Mean IRT response patterns.

The data suggest that there is a correlation between student responses and their level of cognition. Kim has not included two important elements. The most obvious is the lack of data for student responses at the evaluation and synthesis levels; levels that constitute critical and creative thinking. The second element is discussed briefly by Kim, but is not included in the four-category response. This element contains four other possible response patterns. For example, students who demonstrate higher levels of cognition without subsuming the lower levels. The eight possible response patterns are described in Table 6.2.

Table 6.2

Revised IRT Response Patterns

Response	1 Knowledge & Comprehension	2 Application	3 Analysis
1, 2 & 3 incorrect	0	0	0
1 correct, 2 & 3 incorrect	1	0	0
1 & 3 incorrect, 2 correct	0	1	0
1 & 2 correct, 3 incorrect	1	1	0
1 & 2 incorrect, 3 correct	0	0	1
2 incorrect, 1 & 3 correct	1	0	1
1 incorrect, 2 & 3 correct	0	1	1
1, 2 & 3 correct	1	1	1

Including data for these response patterns produces the graph shown in Figure 6.2. The correlation evident in Figure 6.2 is not as obvious. Kim (1996) explained this response pattern as being due to random errors and/or guessing by the students. The possibility that the data are erroneous is then dismissed when Kim argued that the data shows that Bloom's taxonomy is not cumulative. An overlooked explanation is that IRT is not valid.

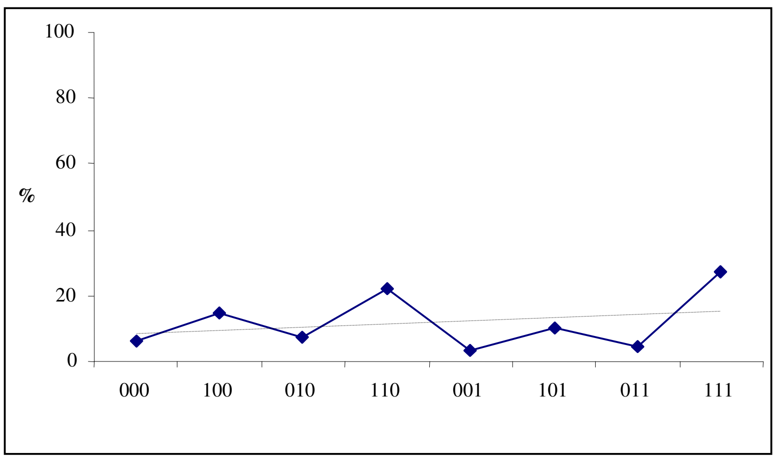


Figure 6.2. Revised mean IRT response patterns.

Yuretich (2002) claimed that multiple choice questions can be designed to address critical and creative thinking, and proffers the example shown in Figure 6.3. This approach requires the student to have an understanding of the concepts (in this instance, ocean currents and winds) and be able to apply them to the given situation.

On the following “continent”, choose the letter corresponding to the place where **coastal upwelling** will most likely to [sic] occur:

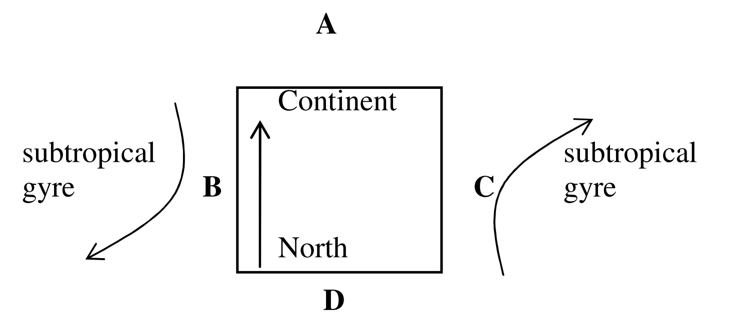


Figure 6.3. Multiple choice question addressing higher levels of thinking.

Kim (1996) could argue that this question is still an example of recall. In studying ocean currents, students would be exposed to diagrams such as those shown in Figure 6.4 (Hovan, 2004). They simply have to recall the basic structure of this earlier diagram and apply it to the test. Application is not generally considered to be a higher order thinking skill.

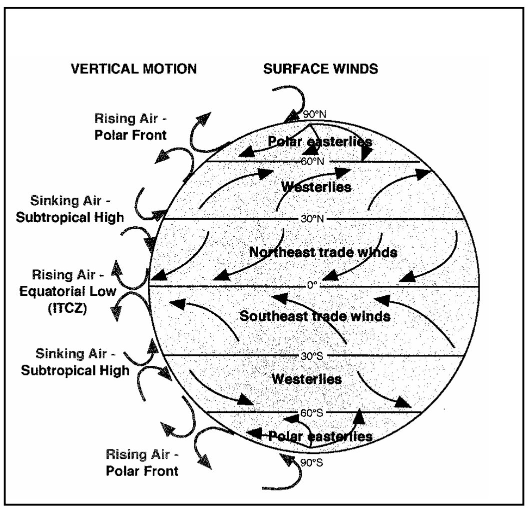


Figure 6.4. Generalised sketch of global atmospheric circulation.

While this style of question may require more than knowledge recall, the structure of a multiple choice question limits the extent to which higher order thinking is employed by the student. The student chooses between predetermined responses, one of which is ‘the’ correct answer. This type of question does not allow the student to consider alternative correct responses that would allow the demonstration of critical and creative thought.

Yuretich provided an interesting solution. A multiple choice test is given twice. The first time it is administered in the usual way, completed individually by students. Next, it is completed in small groups. Defending their initial answer and critically evaluating alternatives with their peers allows students to engage in higher order thinking.

This approach supports the arguments of Baxter, Elder and Glaser (1995), who suggested that student performance during problem-solving activities should be studied. The characteristics commonly displayed by higher order thinking students are described in Chapter Two. These can be used to compile a checklist for student observations to distinguish between higher and lower order activity. Baxter, Elder and Glaser (1995) examined the relationship between students' results when completing a task and the cognitive skills they demonstrated during the task. The observed task was the well-used 'identification of mystery powders' activity.

The researchers assumed that students who display higher order thinking behaviour are more likely to correctly identify the powders than are other students. Lessons were videotaped for future scoring, and included in situ questioning. For example, students observed testing the powders with iodine would be asked "Why did you do that?" This sort of question assumes that the student has given prior thought to their actions. Students who simply follow a previously conducted test may not have given the action much consideration, yet when prompted for an explanation they can provide the stock answer that they are testing for starch. It would require careful analysis to determine if this action resulted from higher order thinking. Nevertheless, their results in Figure 6.5 show that there is a relationship between observed activity and higher scores for the task.

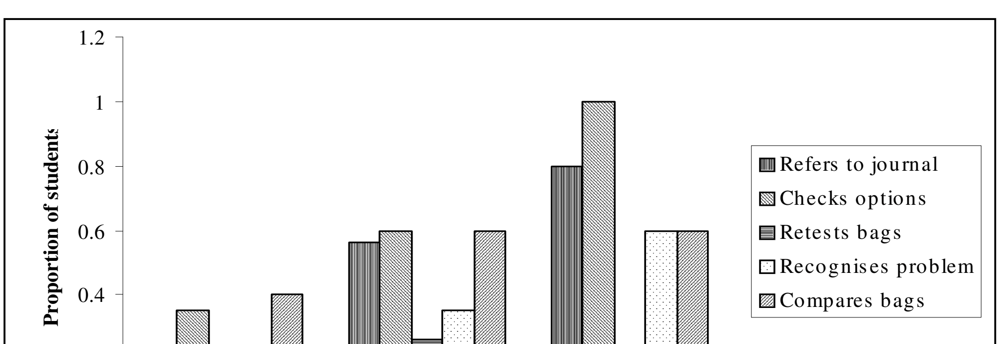


Figure 6.5. Observed student activity and task scores.

The authors do not provide any justification for their choice of categories. It could be argued that, for example, 'Retests Bags' is a routine activity within a laboratory environment and does not necessarily indicate higher order thinking.

6.3 ASSESSING CRITICAL THINKING

Hummel and Huitt (1994) have expressed a concern that the level of critical thinking evident in our students is below the level required for predicted societal demands. They suggested that to improve critical thinking we must first address how critical thinking is measured. The use of multiple choice testing is not recommended as it does not provide any scope for displaying individual critical thought. Assessment of critical thinking skills is only acceptable if it supports illations about the thinking process, rather than only scoring the results of students' reasoning (Norris, 1986, in Simpson, 2002, p. 30). Hummel and Huitt referred to this approach as "forced choice" (Hummel & Huitt, 1994, online). This suggests that they are more in favour of the assessment format favoured by Ennis and Weir (1985), but refining the method of assessment does not necessarily improve students' critical thinking. Hummel and Huitt argued that a revision of assessment techniques could lead to a change in curriculum, resulting in content being taught at higher cognitive levels.

In 1997, Singapore's 'Thinking Program' taught thinking skills to students in their first year of high school. Although it no longer operates, the critical thinking aspects of this program have been examined by Jeffery (2001). The study involved qualitative and quantitative methods to evaluate the perceptions of students regarding the teaching and learning aspects of the program. Jeffery wanted to determine the extent to which critical thinking skills were applied in students' daily lives, not restricted to within the school.

Jeffery (2001) proposed that, for thinking skills to be measurable, there must be observable behaviours that differentiate between students' critical thinking abilities. If there are no observable differences this would indicate that the program was having little effect on critical thinking skills. In doing so, Jeffery (2001) is supporting the arguments of Hummel and Huitt (1994); it is inappropriate to measure critical thinking, which is process oriented, with assessment methods that are product oriented. Measuring implies some form of numerical or statistical manipulation; the evaluation of critical thinking must go beyond this to include the attitudes and behaviours of the students.

Jeffery (2001) supported the use of direct observation of students placed in a problem-solving environment (Baxter, Elder & Glaser, 1995; Fraser, 1998a; Huitt, 1998). In addition to scoring the number of correct answers obtained by a student, this approach allows observations to be made with regards to student behaviour when they have no answer for a difficult problem.

Observations can yield large amounts of qualitative data, which means it is necessary to refine collections and recording methods (Burns, 1997). Jeffery (2001) suggested video recording lessons for later observation and scoring. This has the advantage of allowing the teacher-researcher to be immersed in the teaching-learning aspects of the class and being able to objectively analyse the lesson at an appropriate time. Other observers could view the lesson at their leisure, allowing for inter-rater relationships to be calculated. Jeffery (2001) overlooked the fact that the presence of one or more video cameras may alter the dynamics of the learning environment, as would the presence of extraneous human observers. Furthermore, the positioning of a finite number of cameras controls what the observer can observe.

A rather intriguing statement was made by Jeffery (2002). While the analysis of students' critical thinking must include the qualitative analysis of the school culture and the learning environment, these factors are not included in Jeffrey's research into the Singaporean Thinking Program. Data were collected from student questionnaires, focus-group interviews and student journals. The focus groups were described as simulating the classroom environment in that students are encouraged to express their views without inhibition. An inference that can be drawn is that the presence of cameras in the classroom could inhibit the students' behaviour. Equally, the responses elicited from students in an interview situation will be influenced by the degree of subjectivity inherent in the questions posed (Anderson, 1998).

A study of the development of students' higher order thinking skills within science classes was conducted by Maor and Knibb (1999). Data collection and analyses were enhanced by video taping the lessons and using commercially available software, which allows segments of the video recordings to be coded and indexed. In agreement with Jeffery (2001), Maor and Knibb (1999) concluded that video recording allows the learning environment to be revisited many times to ensure the integrity of the data. It also allows other aspects of the learning environment, such as non-verbal communications between students, to be analysed in context.

Bearing in mind that critical thinking is conducted by people, Haynes and Haynes (2000) recommended that less emphasis be placed on the skills of critical thinking, and greater emphasis on the thinker operating individually and socially within a prescribed learning context. Again, the use of multiple methods of assessing higher order thinking skills is supported. This allows for individually different internal methods of processing data to be integrated, including those that are learnt outside of the classroom.

Haynes and Haynes (2000) pointed out that the language of students is different from the language of teachers. This implies that teacher-developed questions will be interpreted differently by different students. Assessment should not focus on the end product (is the student 'right' or 'wrong') but on the analytical pathway followed. Chapter Two of this thesis indicates a smorgasbord of definitions of higher order thinking. This suggests that the design of a standardised critical/creative thinking test is problematic. The vast array of different contexts in which students are placed (Blatz, 1992, in Haynes & Haynes, 2000, online) demands that any test of critical thinking should allow the assessor to be able to treat student responses individually.

While there may be generalised areas that would be expected to be addressed in forming a solution, this allows for multiple correct answers.

Tests such as the *Cornell Critical Thinking Test* (CCCT) could be used. The CCTT is separated into seven components that measure students' judgement of the reliability of statements, deductive reasoning, value judgement, observation, credibility, assumption and evaluation (Simpson, 2002). Haynes and Haynes (2000) pointed out that as this test is produced in the USA it may be culture specific. Considering the overlap between the American and Australian cultures, through all forms of modern media, the differences in culture specificity are difficult to gauge. However, if there are differences, this reinforces the arguments of Huitt (1994) and Jeffery (2001) to use an array of assessment techniques.

A similar test, the *Watson-Glaser Critical Thinking Appraisal* (WGCTA), was described by Simpson (2002). This 80 item multiple-choice test presents problems associated with the workplace and classroom. The test addresses five elements of critical thinking, namely deductive reasoning, inference, relevance, interpretation and evaluation. Wagner and Harvey (2003) debated that while the content of the test is sound its method is suspect. The multiple-choice nature of the questions, particularly those that require only a true/false response, makes the test susceptible to randomly guessed correct responses.

The first element of this test is made up of five-choice multiple-choice questions. The remaining four elements require only a true/false response. This means that it would be possible for a student to correctly answer one fifth of section one, and half of each of the other four sections by randomly guessing. This equates to 70% of the test being answered correctly by a student who does not have well-developed critical thinking skills.

The WGCTA has been further studied by Gadzella, Stacks, Stephens and Masten (2005), to determine if it is a valid and reliable instrument for the measurement of critical thinking by students contemplating a career in education. This follows from poor internal reliability reported by Loo and Thorpe (1999, in Gadzella, Stacks, Stephens, & Masten, 2005, online). While it was found that the split-half reliability

(0.44) was lower than those reported in the accompanying manual, the researchers explain that they used a relatively small sample.

Many schools and colleges utilise online technology for the delivery of course materials, and as an integral part of the teaching-learning process (Kessell, 2001). While much discourse takes place in real-time (synchronous), there is considerable asynchronous dialogue. This approach allows students to study course materials, in depth, in their own time, and converse with experts in other time zones (Bajjaly, 2005). However, Murphy (2004) stated that although this type of communications encourages cognitive activity it does not assure it.

When examining the contribution of software towards the development of higher order thinking Stoney and Oliver (1999) devised a checklist to record the observable cognitive engagement of students. Their checklist was specifically designed to identify and record elements of lower and higher order thinking that could be observed when using a unique piece of software. A more general approach has been adopted by Murphy (2004). Murphy designed an instrument by which critical thinking within an online, asynchronous discussion can be measured by synthesising existing models. The principal behind this instrument is that higher order thinking is not derived from the medium in which a course is delivered, but from other factors such as instructional design, the quality of the dialogue moderator and the personal characteristics of those involved in communications. Also, the topic being discussed must not be overlooked! The main characteristics of the existing models, and the resultant instrument designed by Murphy (2004), are summarised in Table 6.3.

While this model appears similar to the hierarchy of thinking proposed by Anderson and Krathwohl (2001), Murphy is describing the phases of development within critical thinking. Specific indicators for each phase, that can be observed and scored in a learning environment, are shown in Table 6.4.

Table 6.3

Synthesis of Four Models of Critical Thinking

Murphy (2004)	Brookfield (1987)	Norris & Ennis (1989)	Bullen (1998)	Garrison, Anderson & Archer (2001)
Phase 1: Recognise	Trigger event: Exposure to unforeseen event resulting in inner discomfort & perplexity	Elementary clarification: Attaining a level of clarification through analysis	Clarification: Appraising the nature of a dilemma	Triggering event: Identifying an issue
Phase 2: Understand	Appraisal: Appraising the situation	Basic support: Judging sources for credibility	Assessing evidence: Judging sources for credibility	Exploration: Thinking about ideas
Phase 3: Analyse	Exploration: Seeking a resolution	Inference: Making & judging inferences		
Phase 4: Evaluate	Developing alternative perspectives: Developing new ways of thinking & behaving	Advanced clarification: Forming, judging & evaluating definitions	Making & judging inferences: Inferring & making value judgements	Integration: Generating meaning from the Exploration phase
Phase 5: Create	Integration: Negotiating with new perspectives to facilitate change	Strategies & tactics: Interacting & deciding on an appropriate action	Using strategies & tactics: to guide thinking to reach a conclusion	Resolution: Proposing or applying a solution to an issue

Murphy (2004) has demonstrated a thorough analysis of the existing models. By explaining that not all indicators will be relevant in all contexts, Murphy acknowledged the diverse definitions of critical thinking. Whether all of the indicators have to be met for a particular level to be achieved is not clear, and this would need to take into account the specific context in which the observations were made. Analysis of text based on sentences is relatively straightforward, albeit unwieldy given the length of dialogue generated in one session. The use of this model has been limited to online, asynchronous discussions. This limits other factors such as synchronicity of responses, impulsive building on ideas such as in a social constructivist environment. In a school setting this approach would need to be modified to include the interactions that take place between students and their teacher, verbal and non-verbal.

Table 6.4

Indicators for Murphy's Phases of Critical Thinking

Phase	Code	Indicators
Recognise	R1	Recognising and/or identifying an issue
Understand	U1	Exploring and identifying what is relevant to the issue
	U2	Locating background information
	U3	Locating alternate perspectives on the issue
	U4	Making observations
	U5	Clarifying or judging the nature of the issue
	U6	Questioning and exchanging information.
Analyse	A1	Engaging in new ways of thinking and/or behaving.
	A2	Classifying evidence and/or perspectives.
	A3	Differentiating similarities & differences
	A4	Interpreting and explaining the issue.
	A5	Breaking down the problem into components
	A6	Identifying & filling gaps in & judging one's own thinking
Evaluate	E1	Judging the validity and relevance of information
	E2	Reviewing perspectives and assumptions.
	E3	Detecting inconsistencies
	E4	Making and judging definitions.
	E5	Using evidence to support arguments.
	E6	Retaining and/or rejecting evidence
Create	C1	Implementing strategies.
	C2	Applying actual or hypothetical solutions
	C3	Constructing new knowledge or perspectives.
	C4	Generating alternative hypotheses and perspectives.
	C5	Acting on a solution, decision, or conclusion.
	C6	Executing a plan.

In addition to the CCTT (Ennis, Millman and Tomko, 1985, in Simpson, 2004, p. 44), Ennis was involved in the creation of a more open-ended instrument, the Ennis-Weir Critical Thinking Essay Test, or EWCTET (Ennis & Weir, 1985). This test assesses critical thinking within the framework of debate. An argument is presented, to which the student has to produce a response. By responding in paragraph form, students are not restricted to pre-determined 'correct' answers required by a multiple choice test. The choice of supporting or refuting the argument is at the discretion of the student; there is greater emphasis on the logical approach to the response rather than the adoption of a particular stance. Unlike a rigid multiple choice answer key, the marker is advised to use the marking key as a guide "tempered by the grader's judgment" (Ennis & Weir, 1985, p. 7).

Two disadvantages with this approach are evident. Marking essays is a time-consuming process, which also requires considerable familiarity with the answer key.

Allowing marks to be allocated at the discretion of the marker raises the concern of inter-rater reliability (Rane-Szostak & Robertson, 1996, in Simpson, 2004, p. 46). Initial samples of 27 and 28 students were independently marked by two examiners, with reported reliability coefficients of 0.86 and 0.82 (Ennis & Weir, 1985). It could be argued that these sample sizes are quite small; further statistical data is provided by Ennis (1998) after the test had been in use for 13 years. These data are summarised in Table 6.5.

Table 6.5

Inter-Rater Reliability Coefficients for the EWCTET

Group	Sample size	Inter-rater reliability coefficient
1st Year US university	27	0.86
1st Year high school	28	0.82
1st Year US university	1617	0.93
Asian junior college for women	36	0.72
1st Year US university	99	0.90
Undergraduates US university	187	0.83

The consistently high reliability coefficients support the initial evidence that this test is reliable. Furthermore, its application across universities, colleges and high schools in western and Asian cultures suggest that the cultural bias is minimal.

6.4 ASSESSING CREATIVE THINKING

Chapter Two defines higher order thinking skills as the mental processes allowing students to develop factual, procedural, conceptual and metacognitive knowledge within the creative and critical domains described by Anderson and Krathwohl (2001). De Bono (1970, in Cheek & Streichler, 2000 online) further described creative thinking as being composed of lateral and vertical thinking. Lateral thinking can be viewed as the broad scope of solutions to a problem, which do not have to be correct; in some regards this is the 'brainstorming' aspect of creativity, in which the number of solutions does not have to be limited. Vertical thinking selects specific lateral aspects and analyses them in greater detail until a final solution is reached. When measuring the degree of creativity it is therefore necessary to consider both the lateral and vertical components.

This measurement of creativity is described by Jackson (2005) as being one of the most challenging tasks for teachers. It could be inferred that this is because creative thinking is more cognitively demanding than critical thinking, supporting the reversal of their cognitive order by Anderson and Krathwohl (2001). His statement that creativity is recognised only when it is seen is somewhat reminiscent of the approach alluded to by Resnick (1987), described in Chapter Two.

Cropley (2001) maintained that creativity tests are a better indicator of creative life achievements than are more generalised IQ tests or school grades. He described four domains of creative thinking, shown in Table 6.6. Using a binary approach individuals are categorised as either having, or not having, the traits necessary to meet the requirements of each domain.

Table 6.6

Cropley's Domains of Creative Thinking

	Category															
Domain	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Knowledge	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Thinking skills	+	+	+	+	-	-	-	-	+	+	+	+	-	-	-	-
Motivation	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	-
Personality	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-

Categories one through to five demonstrate varying degrees of creative thinking. These have been named

1. Fully realised;
2. Stifled;
3. Abandoned;
4. Frustrated; and
5. Pseudo-creative;

respectively. All of these categories address three out of the four domains, except for category one, *Fully Realised*. The remaining categories numbered 6 through to 16 are not named. Cropley (2001) seems to ignore them; the assumption is that they indicate extremely low levels of creative thinking. The binary system used by Cropley (2001) is quite limiting for two reasons. First, it does not allow for any overlap of content between the domains. It is difficult to perceive a system in which an individual's skills in thinking are completely divorced from their knowledge of a particular subject. Secondly, there is no allowance for degrees of thinking skills or depths of knowledge. The realisation that an individual has, or does not have, a personality could be quite alarming!

Uban (1990, in Cropley, 2001, pp. 145-7) proposed a system in which no single component is responsible for creative thinking. Each domain integrates to some extent with the others. This suggests that the assessment of creative thinking may require more than one type of measuring instrument.

Jackson (2005) has suggested that attempts to assess creativity can actually be suppressors of creativity. This charge is levelled particularly at forms of outcomes based education, in which the measured outcome is predetermined. Learning is derived from creativity by numerous pathways, yet outcomes based approaches centre on the end results rather than the methods by which the results are achieved.

Within the constructivist learning environment described in Chapter Three, learning is an active process. Activities include the planning, designing, constructing and evaluation of cognitive and physical products. It becomes necessary to assess all of these creative steps, which may not always be possible by traditional tests. Cheek and Streichler (2000) suggested that aspects of creativity can be determined through portfolio assessment, where the portfolio contains these elements of the learning journey. The scope of a portfolio will largely be determined by the subject it addresses. When working with Year 10 students studying a program entitled *Creative Thinking and Technology* (CTT), Cheek and Streichler proposed the portfolio profile shown in Table 6.7.

Table 6.7

Portfolio Assessment Criteria

Criteria In Portfolio (Group 1)	% Weight	Group 2	Group 3	Group 4	Group 5	Teacher
Originality	10	9	8	8	10	10
Usefulness	25	24	18	23	20	24
Considering all factors	15	10	10	9	10	12
Computer program feasibility	20	19	18	18	20	19
Technical quality, graphic editing and design	10	6	7	7	10	6
Interesting subject	10	8	7	7	10	7
Complexity – number of subsystems / procedures	10	4	7	5	10	5
Total	100	80	75	75	90	83

The marks assigned to the elements within a portfolio include peer-assessment and teacher-assessment, but no self-assessment. This supports the research of Jackson (2005), who stated that while students can make judgements about their own beliefs, these judgments are subjective and may not be consistent. The elements address both the lateral and vertical components described by de Bono (1970, in Cheek & Streichler, 2000, online). At the same time, this restricts the metacognitive perspective of the students. The criteria for awarding particular scores are not described. The class had preceded this activity by completing thinking skills activities outlined in the CoRT program (de Bono, 1979, in Chance, 1986, p. 11). It is assumed that the scores somehow relate to these previous activities.

The authors claimed that the results show a high internal consistency between the groups' and teachers' scores. This is true for most elements, but the authors seem to have overlooked the results for 'Complexity – number of subsystems / procedures', in which scores range through four marks out of a possible ten, to the full ten marks. It is further claimed that higher order thinking skills can be measured by techniques such as comparing the initial product to the final result. This contradicts the earlier statements that pointed out that students did not see the value in submitting plans and drafts, and constantly asked why it had to be done. Cheek and Streichler (2000) were working with students that had been labeled as low-achievers. With a different cohort it is possible that a more positive response would have been encountered. It could be further argued that demanding they adhere to a strict format for their portfolios further stifles creativity.

In his discourse on the assessment of student creativity, Jackson (2005) stated that the factor to be considered include ideas, processes and the resultant outcomes. Each of these elements can be further divided, addressing

- The quantity of ideas forwarded;
- The quality of those ideas;
- Use of knowledge relevant to the context of a given problem;
- Attitudes;
- Critical thinking;
- Justifications for a particular solution; and
- Originality.

When analysing this research, Craft (2001) described the emerging field of psychometrics; the use of tests to quantify human abilities (Kline, 1998). Factors perceived as relevant to the subject of a test are responded to in a 'Yes/No' fashion, or by placing oneself on a continuum (for example, 'strongly agree' - 'agree' - 'don't know' - disagree' - strongly disagree'). In order to address these factors many tests were developed during the last century. Torrance (1989, in Cropley, 2001, p. 101) has identified 255 different tests, each with an idiosyncratic emphasis.

The creation of instruments to measure creativity developed by Guilford (1950, in Craft, 2001, online) led to the development of the Torrance Tests of Creative Thinking (TTCT; Torrance, 1966; 1974; in Craft, 2001, online). Torrance regarded creativity as a process of identifying a problem, testing new solutions to the problem and communicating the results to others, based on his earlier military experiences (Torrance, 2001). The Torrance Tests measure four factors of creative thinking, labelled Fluency, Flexibility, Originality and Elaboration.

Within these tests, Fluency is defined as the number of meaningful responses to a question. Flexibility extends Fluency by emphasising the examination of a situation from different perspectives. Originality refers to the number of responses that are considered unusual or rare, and elaboration is defined as the addition of detail to an answer (Grieshober, 2004).

Torrance regarded this collection of tests to be suitable for the full spectrum of students, with respect to their cognitive and creative abilities. Murray (c2001) took a different view. In her work with autism Murray defined monotropism as a cognitive condition in which the individual focuses only on one activity, and polytropism as a focus on multiple activities. Murray claimed that the Torrance Tests measure a quantitative difference, thus differentiating between monotropism and polytropism rather than degrees of creativity. Unfortunately this contention was not substantiated with any data or logical argument.

Craft was rather critical of the Torrance Tests, claiming that they only measure "creativity on request" (Craft, 2001, online) and have little to do with creativity in context. This argument could be considered true of any test. Few people will spontaneously sit a test. They usually wait until they are invited, or are obligated to do so. Craft used the argument of de-contextualisation to explain why the Torrance Tests are no longer used, but in doing so seems to have overlooked the fact that, after their publication in the 1960s and 1970s, they have been revised and republished in 1999 (*2005 STS catalog of products and services*, 2005). It does suggest, however, that any test of creativity should be reinforced by observations and measurement of creativity in situ.

The latter point is reinforced by Edwards (2001). At the 51st Conference of the Australian Science Teachers' Association, this educator, with over 30 years experience, shared his personal observations of the Torrance Tests:

> The students work through a series of exercises. In Form B they eventually get to:
>
> Activity 5: Unusual Uses (Tin cans)
>
> "Many people throw their tin cans away, but they have thousands of interesting and unusual uses. In the spaces below and on the next page, list as many of these interesting

> and unusual uses as you can think of. Do not limit yourself to any one size of can. You may use as many cans as you like. Do not limit yourself to the uses you have seen or heard about; think about as many new uses as you can."
>
> "OK class, you have 10 minutes", click goes my stopwatch. And I walk around the room. It is a hot November afternoon in Townsville and someone has forgotten to turn the fans on. I can hear most of them silently moaning: "Tin cans? The guy's got to be joking!" After the 10 minutes I say "Stop, don't turn the page until I tell you to" and what do we have next?
>
> Activity 6: Unusual Questions.
>
> 'In this activity, you are to think of as many questions as you can about (You guessed it!) TIN CANS....'
>
> Even the students that went along with the last one by this time are thinking: "He really has got to be kidding". (Edwards, 2001, online).

Edwards demonstrated that the style of these tests does not appeal to the students. According to conative theory (Huitt, 1999), if students are not cognitively engaged it is reasonable to assume that their creative thinking skills may not be best displayed, or measured.

6.4.1 Creative Thinking in Science

Simonton (2004) has proposed that creativity within science has four precursors, namely logic, socio-cultural context, genius and random chance. His argument is based on a series of assumptions gained from analysing the original publications of scientists during their careers.

Scientists developed their education and professional experience from a larger set of ideas and other factors such as scientific concepts, laws and facts, collectively called a scientific domain. The elements within a domain adopted by a scientist are unique to that scientist. While many scientists will share common elements they maintain individual differences. Consequently, a scientist can be considered as a subset of a given domain. The number of elements in a subset will vary as some scientists specialise in one area, whiles others adopt a more generalised stance. Also, the number of scientists working within a given domain will vary.

The subsets are submitted to random recombinations of elements. This has been referred to by Einstein as “combinatorial play” (1949, in Simonton, 2004, p. 46). An analogy can be drawn between this phenomenon and the random mixing of alleles during mitosis. The difference being that scientists actively search for useful permutations rather than relying on the slower evolutionary process. The ‘publish or perish’ syndrome leads to a rapid exchange of ideas regarding these permutations. Many are rejected.

Simonton (2004) purported that the random chance of creativity occurring is supported by the logical approach of the scientist. This limits the range of elements considered to those that are perceived to have some logical connection to a possible solution. This must, therefore, limit the degree of random assortment. Concurrently, the concept of geniusness is applied. Simonton defined this as the ability to generate unusual associations between elements, allowing scientists to set aside their usual logical constraints.

The fourth factor, socio-cultural context, cannot be overlooked. What may be considered as a logical process in one social sphere may be viewed differently elsewhere. The social context can prejudice the logic. All four factors are interlinked. Simonton has assumed that three are subservient to chance, yet it could be argued that any factor dominates the remainder by exerting its influence. A more pragmatic interpretation would consider all four factors equally.

Based on the structure of the TTCT, and supporting the arguments of Bradley (2005), Carr (1990), and Haynes and Haynes (2000), a context-specific creative thinking test has been designed (Hu & Adey, 2002). The Scientific Creativity Structure Model (SCSM) is a seven-question test in which students’ creative thinking skills are applied to scientific problems.

Hu and Adey proposed that scientific research needs creative thinking to allow us to move beyond existing knowledge and skills. This applies equally to research laboratories and students at school, if those students are to become scientists or simply understand the scientific process. Drawing on the work of Alexander and Amabile (1992; 1987; in Hu & Adey, 2001, online) they argued that general creativity tests do not allow subject specific skills and knowledge to be addressed.

This approach is not new. Hu and Adey cited the earlier tests devised by Friedlander (1983); Majumdar (1975); and Sinha and Singh (1987) (in Hu & Adey, 2002, online). In what may appear as a direct contradiction of the reasons for creating the SCSM, Hu and Adey argued that these tests have a high dependency on scientific knowledge and could not be used effectively by high school students with relatively limited knowledge of science.

However, Hu and Adey maintained that a test can be designed to address the context of science, addressing elements such as problem recognition and experimental design, without needing specific scientific knowledge. More general tests, such as the Torrance tests, address broader issues that span all learning areas. As a measure of general creative thinking they are adequate yet may not provide details regarding creative thinking within any specific context.

Another consideration is that of cross-culture pertinence. The science tests alluded to above were designed for specific cultural contexts and may not have a general applicability. Hu and Adey designed their test initially working with teachers in China and later testing it with students in the UK. Questions relate to a piece of glass, space travel, a bicycle, gravity, a square and a fruit-picking machine, and were found to be relatively free of cultural bias.

The SCSM is a three-dimensional test, in that it addresses three aspects of creativity. Namely, the creative process, the creativity of the individual and the end-product of creativity. Fluency, Flexibility and Originality, described by Torrance (1974) constitute the creativity of the individual. The end-product dimension contains elements of technology, knowledge, an understanding of scientific issues and problem-solving. The creative process, as defined by Hu and Adey (2001), is best described by referring to the biological processes of thinking detailed in Chapter Three. Within the SCSM, this dimension contains the elements of imagination and thinking. The arrangement of these three dimensions is shown in Figure 6.6.

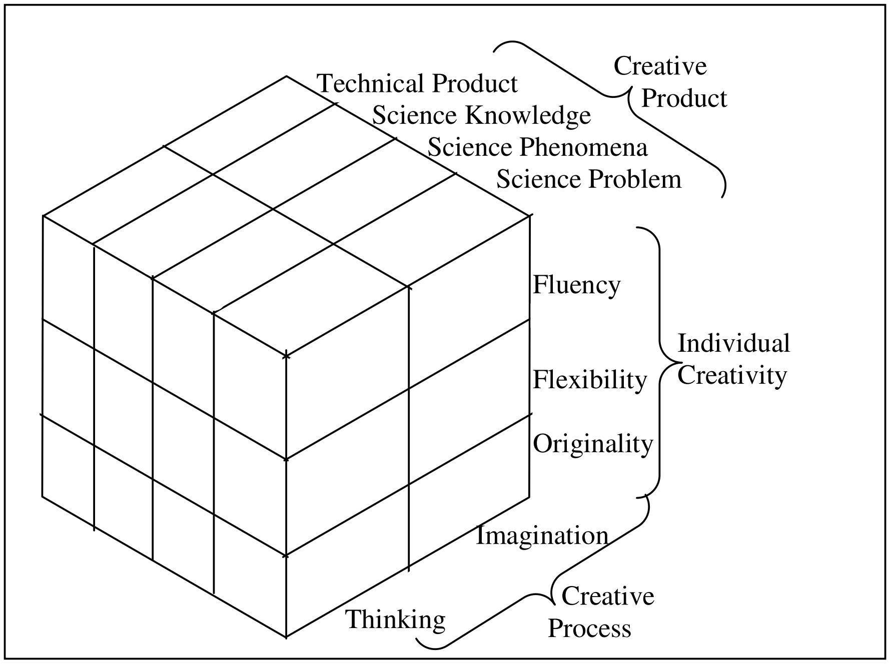


Figure 6.6. The three dimensions of the SCSM.

A fourth dimension, the learning environment in which the creativity takes place, is considered by Hu and Adey to be beyond the control of the students, and so is not represented in their model. Angeloska-Galevska (1996, in Craft, 2001, online) suggested that teacher characteristics need to be included. These include the teachers' attitude towards creativity and the teacher-student relationships. While these may not be included in the SCSM, they can be examined using learning environment survey instruments described in Chapter Five (Fisher, Fraser, & Cresswell, 1995).

The seven questions are designed to address all of the elements shown in Figure 6.6. While this instrument is relatively new, and there is little statistical data available, the authors reported inter-rater reliability coefficients for each question ranging from 0.79 through to 0.91, suggesting that the test is reliable. The authors also reported high degrees of construct- and face-validity (Hu & Adey, 2001).

6.5 ASSESSING COGNITIVE FLEXIBILITY

In 2004, a study was undertaken to examine the relationship between intracerebral communications and cognitive flexibility (Fleisher, Barasch, Feigenson, &

Steineman, 2004). Fleisher, et al., modelled their research on the earlier work of Isen and Daubman (1984), who examined the influence of positive affect on cognitive organisation. Both Fleisher, et al., (2004) and Isen and Daubman (1984) based their method on that of Rosch (1975). Rosch had developed a semantic categorisation model, in which students had to rate, on a scale of one to ten, the degree to which objects belonged in a given category. For example, classifying 'wallet' and 'shirt' in the category 'clothing'. A score of one would indicate that the article did not belong in a category. Scores between two and four (inclusive) also indicated that the object did not belong, but was somehow similar, to the category. Scores of five and above indicate the degree to which an article did belong.

Fleisher, et al., (2004) has used this model as a measure of cognitive flexibility, rather than for its intended purpose or measuring cognitive organisation. As a given object is only judged within one category the rationale for using this model to measure cognitive flexibility is obscure. Fleisher, et al., (2004) have not addressed the validity of this instrument in this instance. While Rosch (1975) reported a split-half reliability of 0.92 ~ 0.97 (N = 78 ~ 131) for her work, the reliability of data for Fleisher, et al., (2004) is not conveyed.

Preceding this research Berg (1948) developed the Wisconsin Card Sorting Test (WCST), which has since been used to measure cognitive flexibility (Kriete & Noelle 2005; Kelley, Yeager, Pepper, & Beversdorf, 2005; Goldstein, Haas, Shemansky, Barnett & Salmon-Cox, 2005; et al.). The test consists of a pack of cards in which the cards display different symbols, colours and numbers of symbols. Subjects have to sort the cards according to a rule that they first need to identify by trial and error. When it has been established that the subject has learnt the rule, the rule is changed. Data concerning the numbers of errors made, and the subjects' inferences about the nature of the task, are used to calculate levels of cognitive flexibility.

This approach supports the pattern-seeking behaviour of humans described by Lowery (1998) and Tripp (2001), referred to in Chapter Three. While it has been used in the succeeding decades from 1948 it predates the work of Spiro by 40 years. Spiro, et al., (1991) regarded cognitive flexibility as the restructuring of knowledge within ill-structured domains. The WCST is a highly structured test situation with specific rules. While participants have to identify changing rules, the rules are only applied within the WCST and not to new situations.

Another approach is to measure cognitive flexibility indirectly. The degree to which ICT is applied within a learning environment can be determined via the LoTI instrument (Moersch, 1999). The effect of ICT on the different learning areas can be determined from students' scores from the non-ICT specific EWCTET and SCSM instruments.

6.6 SUMMARY

Critical thinking is fundamental to the curriculum. Whether critical thinking should be taught as a subject itself, or embedded in the context of specific learning areas, is the subject of debate (Bradley, 2005; Carr, 1990). If critical thinking is considered as a means by which knowledge can be developed then, irrespective of the method by which they have been gained, the student should be able to apply these skills in any given context.

Hummel and Huitt (1994) have suggested that revising the methods by which critical thinking is assessed could result in the achievement of higher levels of thinking. This assessment should be able to measure students' inferences during the thinking process, rather than just the outcomes. Jeffery (2002) purported that the measurement of thinking skills should include observable behaviour, and this should take place within the context of a problem-solving environment.

Offering support to the rearrangement of Bloom's taxonomy by Anderson and Krathwohl (2001), Jackson (2005) argued that the evaluation of students' creativity is probably the hardest teaching/learning challenge faced by teachers. Uban (1990, in Cropley, 2001, pp. 145-7) has suggested that the different domains embedded within creative thinking interact and affect each other. It may be necessary to use more than one instrument to measure creativity.

A solution has been proposed by Hu and Adey (2002). The development of a context specific (but not subject specific) instrument that includes elements of problem recognition and experimental design, without needing specific subject knowledge, allows the dimensions of creative thinking to be assessed.

This chapter has outlined approaches that can be taken when measuring higher order thinking skills. Chapter Seven examines a selection of case studies in which attempts have been made to assess higher order thinking within culturally diverse, technology-rich earning environments.

CHAPTER 7

DEVELOPING HIGHER ORDER THINKING WITH COMPUTERS

7.1 INTRODUCTION

A few years after leaving school I bought my first computer, complete with twin 5¼" floppy drives (hard drives were still relatively new) and a monitor capable of displaying 16 colours. This was about the time Bill Gates uttered the infamous understatement "640K ought to be enough for anybody" (Gates, 1981, online). Since this time there has been a logarithmic growth in the development and application of computers throughout society. Papert (1972) described the integration of technology and education as a thinly camouflaged attempt to use new gadgets to teach the same materials in the same ways. His purpose was to present a visionary change in education, in which computers are not used to process students but are used by students to become innovative thinkers.

Chapter Four highlights two points of view with regards to computers and their effect on education. In this chapter five case studies are presented, in which computers have been integrated with education. The strengths and weaknesses of the different cases, and the effects on the development of higher order thinking, are discussed. The chapter concludes with lessons drawn from the case studies.

7.2 CASE 1: UNITED ARAB EMIRATES UNIVERSITY

Saunders and Quirke (2002) described the effects of introducing laptop computers into Middle Eastern universities. While the United Arab Emirate (UAE) is regarded as a modern country with a sound technological infrastructure it has a culture that is embedded in the traditions of the Bedouin ancestors and their Islamic faith. Secondary school curricula are teacher-centred with an emphasis on the lower order thinking skills. In 1977, the United Arab Emirate government opened the UAE University, which meant that their citizens could complete tertiary education within their own country. This was supplemented in 1998, when Zayed University permitted the entry of female students. Given the traditional secondary curricula, it was realised that tertiary students would need to improve their higher order thinking. One strategy was to introduce compulsory laptops for all students. It was believed that this would give students greater responsibility for their learning and increase their research skills.

In conforming with Islamic teaching, education is only co-educational at the kindergarten level (Al-Adhab, 1992, in Saunders & Quirke, 2002, online). Students entering tertiary institutions had little exposure to either students or teachers of the opposite sex. Likewise for the teachers.

Male students were quick to adopt the technology, believing it would provide quick and simple answers to set problems. Their preferred approach was to work individually or in pairs. Female students showed greater interest in small group work and in producing higher quality work.

Female teachers in male-student dominated classes found that there were more demands on their time to supply the answers. It seems that the single or pair approach by the male students reduced the learning benefits that could be achieved through a more social constructivist setting. The laptops were perceived by the students as providers of greater access to the world beyond their country's borders. Male students felt that there were no differences in the way that they learned compared with the female students; a belief that was not shared by the female students or either group of teachers.

Male teachers working with female students felt a degree of inhibition created by the laptop computers. Their presence meant that teachers often had to lean over their students; a behaviour not generally accepted within this cultural setting. Many of the advantages of technology that have become evident in western cultures became evident, such as the ability of teachers to focus on weaker students without holding back their peers.

Four elements were identified as being essential when introducing new technology into the curricula: culture, gender, infrastructure, and faculty. It is not clear exactly how these elements were identified; there is no mention of any specific qualitative or quantitative techniques that were employed. The lack of any empirical data suggests that no quantitative measures were made. An analysis of the paper further suggests that the only qualitative technique used was the informal interviewing of various participants. However, it is quite clear that the cultural setting has an impact on how the technology is used. The authors reported that the majority of students did not think that culture played a significant role, an opinion which may itself be a result of this cultural setting.

7.3 CASE 2: AUSTRALIAN SECONDARY COLLEGE

In 2001, a new senior college opened in a low socio-economic area of Perth. This college focuses on industry and community partnerships, and innovative methods of learning that incorporate ICT. By implementing the WebCT software system, teachers are able to create teaching-learning programs accessible outside of the school, seven days a week. Trinidad, MacNish, Aldridge, Fraser, and Wood (2001) presented a report based on the use of ICT by Year 11 students and their attitudes towards ICT.

Through the observation of classes and the interviewing of students it became clear that computers were used by most students in most classes. The uses to which they were put centred on researching the Internet, accessing course information and typing up assignments. Ninety per cent of students also admitted to using class time to contact their friends via email, in some cases spending up to 50% of their class time on this activity.

When asked if they thought the ICT helped improve their understanding of various subjects their responses proved to be surprisingly metacognitive. Comments include:

> *Not really, it depends on me not the computers!*
>
> *The technology doesn't get you better grades; it just makes it easier to do the work. It might help you get better grades because of the way that you do it. For example you can put pictures into your work that will make the presentation better. It might also be better to get [information] off the Internet rather than from books.* (Trinidad, et al., 2001, online).

Whilst generally supportive of the technology the students did not believe that it had a great bearing on their education. They were united in their opinion that the teachers should play a central role, and many felt that this was not provided with the online courses. Other students, whose preferred learning styles did not include technology, found the computers frustrating and would prefer their teachers to provide the answers rather than trying to find them on the Internet. To quote one student:

> *Teachers can use different words and ways of explaining to make it clear, whereas online course instructions only have written stuff.*

Again, this study is lacking in quantification. Qualitative techniques included field notes taken during classroom observations, document analysis and interviews. The authors state that the research shows similar results to other studies with regards to the use of computers. Students seem to spend most of their time word-processing, and Internet time is divided between research, email and entertainment. A cynical interpretation would be that, having invested a lot of money, nothing has changed, as earlier pointed out by Papert (1972).

The study showed that most students regard the technology positively, which may have some effect on the standard of their work. However, their comments suggest that the technology is being used purely as a productivity tool and not a mindtool, as described by Jonassen (1996) in Chapter Four. The students who are not comfortable with the technology, about 10% (Trinidad, MacNish, Aldridge, Fraser, & Wood, 2001), seem to feel that they are left out; a situation that needs to be addressed.

7.4 CASE 3: AUSTRALIAN UNIVERSITY

Critical thinking has been regarded as a core component of cognitive development and, therefore, of social progress (van Gelder, 2001). A Department of Employment, Training and Youth Affairs (DETYA) report described critical thinking as a commodity that, while valued, is in short supply (Nielsen, 2000, in van Gelder, 2001, online). In response, the University of Melbourne compels students to study either English, History or Politics as a means of developing critical thinking. By their own admission, this has only been partially successful. Pre- and post-testing of first year and third year students, using the California Critical Thinking Skills Test, produced a change of 0.55 of one standard deviation. By interpolation, it could be inferred that the results for one semester are minimal.

Establishing that higher orders of thinking are not only valued and rare, but are also difficult to teach, a different approach was instituted, based on the Quality Practice Hypothesis. This hypothesis states that critical thinking will only improve if high quality critical thinking is practised routinely, incorporating the transfer of thinking skills developed in one context to another. This is believed to require one-on-one teaching, which has led to the creation of the Reason!Able® applications software.

Reason!Able® helps students structure their arguments by means of a top-down approach. The resulting tree allows the relationships between various parts of the argument to be identified. The structure of the tree is designed by the students as they explore different avenues of the topic under discussion. The visual nature of the tree permits a better understanding of the arguments; branches can be added, moved or deleted as required.

The metacognitive component of higher order thinking is not ignored. Once an argument has been mapped out and edited, users of the software have to examine each component of the argument and evaluate it strengths and weaknesses. Pre- and post-test data for student results from the CCTST demonstrate an increase in approximately one standard deviation over one semester.

The author explains that the software is only one factor in this improvement. Other factors believed to contribute include the contexts in which Reason!Able® was applied; the experience and skills of the teachers involved; and the founder effect; the increased levels of enthusiasm exhibited by students and teachers involved in an innovative project.

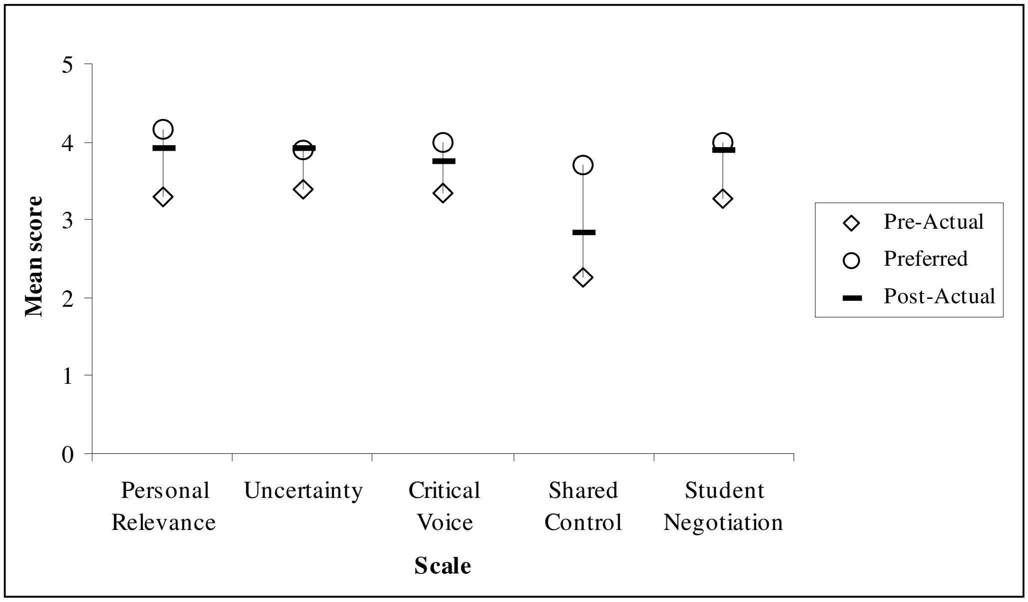
Where the previous case studies have been based only on qualitative data, this study is purely quantitative. Two instruments were used, the CCTST and a written task in which students respond to an argument. The problems associated with multiple-choice tests as a measure for critical thinking have been discussed. These problems have been offset by the written task, which allows a more open response. Data related to the reliability and validity of this test were not included in this study. The description of the task is similar to that of the EWCTET (Ennis & Weir, 1985) described in Chapter Six. It may be worthwhile supplementing the existing data with results from this test. This would add strength to the present findings and could be used to authenticate the written task.

7.5 CASE 4: THAI SECONDARY SCHOOL

IBM first donated a computer to Chulalongkorn University, Thailand, in 1959, initiating the birth of computer education in that country. Early courses in computer-based statistics have evolved into whole degrees in aspects of computing and the application of computers as learning tools in other disciplines. This evolution has necessitated changes in the approaches to teaching and learning, leading to the adoption of a constructivist learning environment. Wanpen and Fisher (2004) used qualitative and quantitative techniques to assess the extent to which constructivism has been incorporated within computer classrooms, and to provide goals for further development.

The first task was to translate the Actual and Preferred forms of the CLES into Thai, and modify them to suit the local socio-cultural context. These revised forms were completed by Thai students. Feedback gained from the forms was used to construct interview questions, ultimately leading to the production of a classroom development plan.

After ten weeks of implementing the development plan the CLES was re-administered to ascertain the extent of any environmental changes. This was supplemented with qualitative data from students' journals, reflecting on their views of the learning environment in ways that may not have been revealed by the



questionnaire. The results are summarised in Figure 7.1.

Figure 7.1. Student perceptions of the learning environment.

Figure 7.1 shows the differences between the students' ideal learning environment (indicated by the 'Preferred' responses) and their perceptions of their actual environment, before and after changes were made to the environment ('Pre-Actual' and 'Post-Actual' responses). The data indicate that it is possible to manipulate factors of the learning environment to make it more conducive for study in computer classes. Student reflections suggest that they found small group work helpful, demonstrating the value of a collaborative approach to learning.

This study showed that technology can modify the learning environment, which may not suit the learning styles of all students. More significantly, it demonstrates that it is possible to measure factors of the learning environment in different cultures, and act on the data in a positive way. The use of qualitative and quantitative techniques provides greater depth of understanding of the learning environment.

7.6 CASE 5: USA PRIMARY SCHOOL

This last case study is of particular interest as it addresses research questions similar to those proposed in Chapter One of this thesis. Based on the premises that

- Learners construct their own knowledge rather than absorb that of others;
- Students can be stimulated to extend their thinking by using technology; and
- Students work best when working collaboratively;

Hopson (1998) devised a study to determine the effects of a technology-rich classroom on students' development of higher order thinking skills, and the attitudes of students towards computers. Specifically, the research questions to be answered were:

> Do students in a Technology Enriched Classroom demonstrate better use of higher order thinking skills than students in a traditional classroom?
> Do attitudes toward computers differ between students in a Technology Enriched Classroom and students in a traditional classroom? (Hopson, 1998, online).

Set within a central Texas primary school, four groups within the student cohort were recognised; Year Five and Year Six students who were enrolled in a technology enhanced curriculum, and students taken from the general population in the respective years. Those students within the technology stream received instruction on the use of spreadsheets, databases and word processors. They also had access to the Internet and CD based materials such as encyclopaedias and atlases. Peripheral devices such as scanners and digital cameras were available. Student tasks included note taking, project and assignment work. Although not specifically stated, it is assumed that they would have undertaken some degree of independent research, given the available infrastructure.

Testing of students' higher order thinking skills and attitudes towards computers were conducted using the *Ross Test of Higher Cognitive Processes* and the *Computer Attitude Questionnaire* (CAQ). Results suggested that there were no significant differences between the groups for Analysis and Synthesis. On this basis, question one was answered in the negative for both year groups. The CAQ results showed no significant difference for the Year Six students and a significant difference for some elements of attitude for Year Five students. Question two was also answered in the negative.

The computer-based activities performed by the students appear to be similar to those identified by Trinidad, et al. (2001); namely, those requiring lower order thinking skills. The conclusions reached by the author appear to be at odds with the presented data. Hopson (1998) reported that the establishment of the technology-rich environment had a minimal, but positive, impact on the attainment of higher order thinking skills. However, both research questions, related to higher levels of cognition and positive attitudes to technology, were answered in the negative. This tends to reflect the paradox demonstrated by Stevenson (1999) in Chapter Four.

The research instigator pointed out this study involved a post-test only. Furthermore, it was not able to account for the influence of home-based computers available to some students. Given these facts, perhaps it would be more appropriate to examine a greater number of factors that could influence the development of higher order thinking.

7.7 LESSONS FROM THE CASE STUDIES

The opening paragraph of this section includes a quote from Bill Gates. There are several quotes that appear from time-to-time at seminars related to technology and education. Some are amusing. All are thought provoking. The more salient ones, shown in chronological order, appear in Table 7.1.

These quotes highlight two points about technology. Whenever a new technology is implemented, some users oppose it. This opposition seems to be based on trying to do things as they have always been done, and an obstinate refusal to learn from history.

The necessity to change our approach to education so that we can best utilise technology is overlooked. This is evident not only in these quotes but also in aspects of the case studies presented above. Albaugh and Knight (1996, in Trinidad, et al., 2001, online) suggested that this opposition is more a function of a resistance towards risk rather than towards technology.

Table 7.1

Technology Quotes

Quote	Source	Date
Inventions have long since reached their limit, and I see no hope for further developments.	Julius Sextus Frontinus, Roman Engineer	AD 10
Students today can't prepare bark to calculate their problems. They depend on their slates which are more expensive. What will they do when the slate is dropped and it breaks? They will be unable to write.	Teachers' Conference	1703
Students today depend upon paper too much. They don't know how to write on a slate without getting chalk dust all over themselves. They can't clean a slate properly. What will they do when they run out of paper?	Principals' Association	1815
This 'telephone' has too many shortcomings to be seriously considered as a means of communication.	Western Union internal memo	1876
Students today depend too much upon ink. They don't know how to use a pen knife to sharpen a pencil. Pen and ink will never replace the pencil!	National Association of Teachers	1907
I think there is a world market for maybe five computers.	Thomas Watson, IBM chairman	1943
It would appear we have reached the limits of what it is possible to achieve with computer technology.	John von Neumann, computer scientist	1949
But what is it [the microchip] good for?	IBM Engineer	1968
There is no reason for any individual to have a computer in their home.	Ken Olson, President of DEC	1977
640K ought to be enough for anybody.	Bill Gates	1981
Any teacher that can be replaced by a computer, deserves to be.	Dr. David Thornburg	1999
For years there has been a theory that millions of monkeys typing at random on millions of typewriters would reproduce the entire works of Shakespeare. The Internet has proven this theory to be untrue.	Anonymous	

The relationship between cognitive and cultural influences is complex; it can be partially understood by considering both factors within the context of a constructivist learning environment (Ewing & Miller, 2002). A key component of this environment is collaborative learning, which, according to Kreijns, Kirschner and Jochems (2002), is restricted by teachers. There is a tendency to keep students 'on task' so that the breadth (and possibly depth) is limited to the task context. Perhaps there is a need to consider the concept of scientific creativity described by Simonton (2004), in which the influence of social activities outside of the perceived learning environment are demonstrated.

Gardner (1983) has described seven multiple intelligences, which have been construed to refer to students' learning styles. Although technology is not specifically identified by Gardner, technology may not be the preferred medium for all students. Trinidad, et al., (2001) estimated that 10% of sample students did not like learning with computers. Ewing and Miller (2002) suggested that that can lead to a feeling of isolation, with possible negative effects on the development of higher order thinking.

Technology-rich learning environments allow students to be involved in simulation activities that allow them to control their learning. Papert (1980, in Cheek & Streichler, 2000, online) described this as combining "Heads-In" and "Hands-On" approaches, conjuring up images of "HI HO, it's off to work we go!" The cost of producing technology-based materials probably falls under the heading of 'aversion to risk' rather than 'aversion to technology'. Nevertheless, it can be a major inhibitor to change. Brahler, Peterson and Johnson (1999) added that the development of these materials is an expensive, resource intensive process, due to the time, expertise and equipment requirements. Estimated times needed to develop technology-based course of various lengths are shown in Figure 7.2 (Marshall, Samson, Dugard, & Lund, 1995, in Brahler, Peterson, & Johnson, 1999, online).

The development times often result in substandard courseware being produced (at a high cost), or no courseware whatsoever. It seems to be more economical to produce courses of about 20 hours duration. Creating a one-off lesson is time consuming; producing a whole course is more efficient. But why develop complete courses?

Lamb (2003) pointed out that you do not need complex technology to produce cognitively sound, technology-based assignments. Lamb suggested concentrating on ways that will engage students in meaningful activities, using technology as a tool to address specific needs. In other words, focus on thinking. Design tasks using keywords from the higher cognitive levels, such as ‘justify’ or ‘evaluate’, and then consider how technology can help students answer the question. Remember to let the students collaborate.

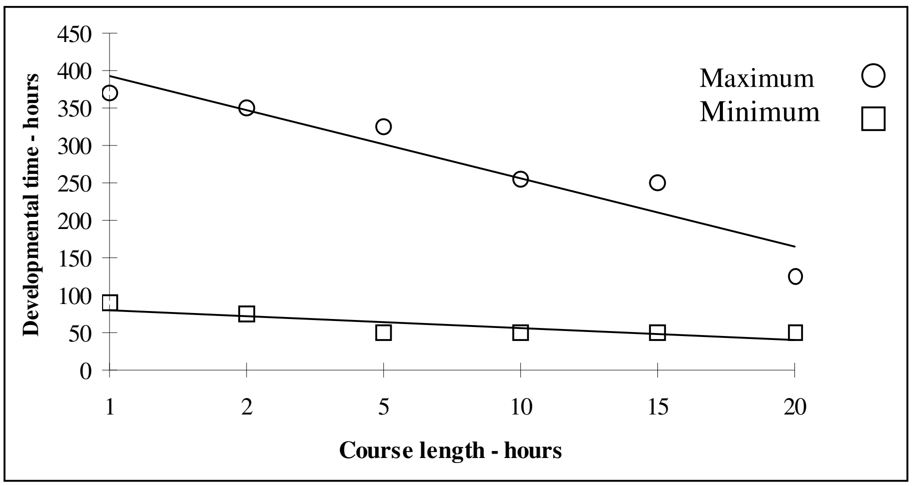


Figure 7.2. Time required to develop one hour of computer-based courses.

Yepes-Baraya (c2001) acknowledged that technology will not produce changes in education on its own. It must be accompanied by reforms in pedagogy and assessment, and teacher-student relationships. The above case studies suggest that the impact of culture cannot be ignored.

7.8 SUMMARY

Chapter Five describes several instruments that can be used to gather data pertaining to the classroom learning environment. Many aspects of the learning environment can be examined; the focus of the research can be addressed by selecting those instruments that provide the appropriate data sets.

Whilst these instruments help to define the culture of the learning environment, a separate approach is needed to measure the levels of thinking that are taking place. The decision as to whether this measurement should be based on generic thinking skills, or those embedded in a particular context, should be made on the basis of the research questions to be answered, tempered with the idiosyncrasies of the learning environment in which the research is based.

Chapters Four and Seven present several concerns related to the implementation of technology in the learning environment. The potential to improve learning through the use of technology has been disputed. Those who argue in its favour are guarded about the extent to which this potential has been achieved. The case studies presented in this chapter highlight the need to apply a mix of quantitative and qualitative research strategies when exploring these concerns. Both approaches have their peculiar advantages and disadvantages; combined they provide a deep exploration of the learning environment.

The next chapter details the methods used to answer the research questions presented in Chapter One. The chapter includes a justification for choosing the case study approach. Data sources and data collection techniques, and the statistical analyses that were performed, are described.

CHAPTER 8

METHODOLOGY

8.1 INTRODUCTION

Shulman (1997), and Cohen, Manion, and Morrison (2000), discussed the types of methodology at the researcher's disposal. The span of methodologies leads to a degree of controversy as to what delineates valid and reliable research. In broad terms, research methods can be classed as quantitative or qualitative. Quantitative research is often referred to as the scientific method; a method that requires a hypothesis, operational definition, some form of experimental control and replication (Burns, 1997). Qualitative methods, which have been described as naturalistic and subjective (Burns, 1997), attempt to report phenomena within their social constructs. The controversy deepens into differing interpretations of social reality, referred to as the subjective-objective dimension (Cohen, Manion, & Morrison, 2000).

Educational research is research into the behaviour of humans. Humans differ from each other, therefore it is unlikely that the same classroom environment can be replicated; neither can all of the inherent variables be controlled. This suggests that the scientific method cannot be applied. Burns (1997) argued that the subjective nature of qualitative research brings into question its reliability and validity. The dilemma expressed by Shulman (1997, p. 21) "There is always a danger that any study undertaken by a practitioner is treated with deference, and any investigation pursued by an outside investigator is greeted with suspicion" can be addressed by using both approaches within one investigation (Burns, 1997).

The description of educational research is complex. Perhaps it is best summarised by Bloom (n.d. in Shulman, 1997 p. 27) "You are permitted to do anything you please as long as you honestly and completely report what you did, how you did it, and your reasons for doing it so that your colleagues are fully informed".

8.1.1 The Case Study

Traditionally, educational research has centred on quantitative methodologies, including experimental, quasi-experimental and survey techniques (Shulman 1997). This approach has the capacity to invalidate the very research being performed. The requirement of the scientific method to establish a control group, and control all variables other than that being manipulated, cannot be achieved in a classroom environment. While many of the obvious variables (time of day, teacher-student ratio, research tool administered, etc.) can be controlled it is not possible to standardise the affective variables that the subjects bring into the classroom. Aspects of students' home lives, or what has happened in the previous lesson from which the student has just arrived, cannot be controlled. Quantitative methods, whilst being well documented, may not be well suited to the qualitative classroom environment.

Drawing on the comment of Bloom given above, the actual paradigms employed should be driven by the research questions that the researcher wishes to answer, not by tradition. It follows that the nature of the questions to be answered will require different methods and approaches. Losh (2001) recommended that in order to negate alternative interpretations of research data, the researcher should collect and measure data in as many ways is as practical.

The case study approach allows both a quantitative and qualitative stance to be adopted. The integration of many and varied types of data permits a broad and deep investigation to be implemented. The complex interaction of these variables allows the researcher to explain how a particular scenario has been manifested (Hancock, 1998).

8.1.2 Cultural Context

Cousin and Jenkins (2001) described a case study as a bounded system. The study takes place within a given setting, which itself could be considered as a larger case. This implies that a case study is nested within a framework that may also contain other case environments. The boundaries of the case study in question must be explicit. This clarifies what the study does and does not include, and provides the cultural setting in which the study takes place. The culture of the environment is significant when interpreting data: They must be considered within the cultural framework from which they were collected.

The boundaries of this case study are well defined. This research took place within an independent, all-girls' school that has a strong emphasis on the cross-curricular use of computer technology. The specific nature of this case study suggests that a wider generalisation becomes problematic, as noted by Adelman, Jenkins, and Kemmis (1980, in Cousin & Jenkins, 2001, online). Applications to all-boys' or co-educational schools may be limited and, broadly speaking, students from lower socio-cultural environments are under-represented. However, Tompkins (1980) maintains that generalising the research findings to other situations is the responsibility of those who interpret the research, and is not the responsibility of the author.

8.2 RESEARCH QUESTIONS AND ASSOCIATED HYPOTHESES

This research was designed to answer the questions:

- What is the relationship between technology-rich learning environments and the development of higher order thinking skills? and
- To what extent are higher order thinking skills demonstrated by students in a technology-rich environment?

The magnitude of these questions is examined by answering the following research questions.

1. What is the relationship between student perceptions of technology-rich learning environments and
    1.1. their attitude towards computers?
    1.2. their level of technological skill?
    1.3. the teacher-student relationship within that learning environment?
    1.4. the development of critical higher order thinking skills?
    1.5. the development of creative higher order thinking skills?

1.6. length of time spent within the environment?

1.7. the age of the technology?

2. What is the relationship between student attitudes towards computers and the
    2.1. level of technological skill?
    2.2. teacher-student relationship within the learning environment?
    2.3. development of critical higher order thinking skills?
    2.4. development of creative higher order thinking skills?
    2.5. length of time spent within the environment?
    2.6. age of the technology?

3. What is the relationship between students' computer skills and the
    3.1. teacher-student relationship within those learning environments?
    3.2. development of critical higher order thinking skills?
    3.3. development of creative higher order thinking skills?
    3.4. length of time spent within the environment?
    3.5. age of the technology?

4. What influences do teacher-student relationships have with respect to the
    4.1. development of critical higher order thinking skills?
    4.2. development of creative higher order thinking skills?

5. Is there a significant correlation between the length of time spent within technology-rich environment and the development of
    5.1. critical higher order thinking skills?
    5.2. creative higher order thinking skills?

6. Is there a significant correlation between the age of the technology and the development of
    6.1. critical higher order thinking skills?
    6.2. creative higher order thinking skills?

7. What is the relationship between students' development of creative higher order thinking skills and their development of critical higher order thinking skills?

Each question examines different aspects of the learning environment, and the relationships that exist between them. These questions are restated as a series of hypotheses to be statistically tested and either accepted or rejected, in conjunction with the acceptance or rejection of the alternate hypotheses. The hypotheses are:

1. Student perceptions of technology-rich learning environments:
   1.1. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and their attitude towards computers.
   H_1: There is a significant correlation between student perceptions of technology-rich learning environments and their attitude towards computers.

   1.2. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and their level of technological skill.
   H_1: There is a significant correlation between student perceptions of technology-rich learning environments and their level of technological skill.

   1.3. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and the teacher-student relationship within that learning environment.
   H_1: There is a significant correlation between student perceptions of technology-rich learning environments and the teacher-student relationship within that learning environment.

   1.4. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and the development of critical thinking skills.
   H_1: There is a significant correlation between student perceptions of technology-rich learning environments and the development of critical thinking skills.

1.5. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and the development of creative thinking skills.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and the development of creative thinking skills.

1.6. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and their length of time spent within the environment.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and their length of time spent within the environment.

1.7. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and the age of the technology.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and the age of the technology.

2. Student attitudes towards computers:

2.1. H_0: There is no significant correlation between student attitudes towards computers and their level of technological skill.

H_1: There is a significant correlation between student attitudes towards computers and their level of technological skill.

2.2. H_0: There is no significant correlation between student attitudes towards computers and the teacher-student relationship within the learning environment.

H_1: There is a significant correlation between student attitudes towards computers.

2.3. H_0: There is no significant correlation between student attitudes towards computers and the development of critical thinking skills.

H_1: There is a significant correlation between student attitudes towards computers and the development of critical thinking skills.

2.4. H_0: There is no significant correlation between student attitudes towards computers and the development of creative thinking skills.

H_1: There is a significant correlation between student attitudes towards computers and the development of creative thinking skills.

2.5. H_0: There is no significant correlation between student attitudes towards computers and length of time spent within the environment.

H_1: There is a significant correlation between student attitudes towards computers and length of time spent within the environment.

2.6. H_0: There is no significant correlation between student attitudes towards computers and the age of the technology.

H_1: There is a significant correlation between student attitudes towards computers and the age of the technology.

3. Students' computer skills:

3.1. H_0: There is no significant correlation between students' computer skills and teacher-student relationship within the learning environment.

H_1: There is a significant correlation between students' computer skills and teacher-student relationship within the learning environment.

3.2. H_0: There is no significant correlation between students' computer skills and the development of critical thinking skills.

H_1: There is a significant correlation between students' computer skills and the development of critical thinking skills.

3.3. H_0: There is no significant correlation between students' computer skills and the development of creative thinking skills.

H_1: There is a significant correlation between students' computer skills and the development of creative thinking skills.

3.4. H_0: There is no significant correlation between students' computer skills and the length of time spent within the environment.

H_1: There is a significant correlation between students' computer skills and the length of time spent within the environment.

3.5. H_0: There is no significant correlation between students' computer skills and the age of the technology.

H_1: There is a significant correlation between students' computer skills and the age of the technology.

4. Teacher-student relationships:

4.1. H_0: There is no significant correlation between teacher-student relationships and the development of critical thinking skills.

H_1: There is a significant correlation between teacher-student relationships and the development of critical thinking skills.

4.2. H_0: There is no significant correlation between teacher-student relationships and the development of creative thinking skills.

H_1: There is no significant correlation between teacher-student relationships and the development of creative thinking skills.

4.3. H_0: There is no significant correlation between teacher-student relationships and the length of time spent within the environment.

H_1: There is a significant correlation between teacher-student relationships and the length of time spent within the environment.

4.4. H_0: There is no significant correlation between teacher-student relationships and the age of the technology.

H_1: There is no significant correlation between teacher-student relationships and the age of the technology.

5. Length of time spent within technology-rich environments:

5.1. H_0: There is no significant correlation between the length of time spent within technology-rich environments and the development of critical thinking skills.

H_1: There is a significant correlation between the length of time spent within technology-rich environments and the development of critical thinking skills.

5.2. H_0: There is no significant correlation between the length of time spent within technology-rich environments and the development of creative thinking skills.

H_1: There is a significant correlation between the length of time spent within technology-rich environments and the development of creative thinking skills.

6. Age of the technology:

6.1. H_0: There is no significant correlation between the age of the technology and the development of critical thinking skills.

H_1: There is a significant correlation between the age of the technology and the development of critical thinking skills.

6.2. H_0: There is no significant correlation between the age of the technology and the development of creative thinking skills.

H_1: There is a significant correlation between the age of the technology and the development of creative thinking skills.

7. Development of creative thinking skills:

7.1. H_0: There is no significant correlation between students' development of creative thinking skills and their development of critical thinking skills.

H_1: There is a significant correlation between students' development of creative thinking skills and their development of critical thinking skills.

The correlations were determined by calculating Spearman's correlation coefficients relevant to each research question.

8.3 RESEARCH INSTRUMENTS

The instruments used were the

- Computer Laboratory Environment Inventory (CLEI);
- Attitude towards Computers and Computer Classes (ACCC);
- Australian Schools Computer Skills Competition (ASCSC);
- Questionnaire on Teacher Interaction (QTI);
- Ennis' Weir Critical Thinking Essay Test (EWCTET);
- Scientific Creativity Structure Model (SCSM); and
- School databases.

For the purposes of testing the above hypotheses, correlation coefficients between data gained from these instruments were derived according to the matrix shown in Table 8.1. For example, hypothesis 1.1 was tested by correlating the data gained from administering the CLEI and ACCC instruments. Hypothesis 2.1 was tested by correlating data from the ASCSC and ACCC instruments. The instruments provide data on individual student perceptions, skills and cognitive abilities, from which class mean scores are derived. Data from these instruments were reinforced with data collected from staff and student interviews, and classroom observations. Additionally, data from the interviews and classroom observations were used to calculate the degree of technology use within the learning environment, as described by Moersch (1999), using the LoTI instrument.

The CLEI and ACCC, were administered as one instrument, delivered electronically. The ASCSC was a 'paper and pencil' test compiled by the University of New South Wales, and marked externally. Students' answers sheets were marked electronically using scanning software. The EWCTET was completed as an exercise using the Reason!Able® software package described in Chapter Seven. This allowed marking to focus on the critical thinking arguments presented, with a reduced influence of the students' competence in English expression.

Table 8.1

Matrix of Research Instruments used to test Research Hypotheses

		Instrument					
		CLEI	ACCC	ASCSC	QTI	EWCTET	SCSM
Instrument	ACCC	1.1					
	ASCSC	1.2	2.1				
	QTI	1.3	2.2	3.1			
	EWCTET	1.4	2.3	3.2	4.1		
	SCSM	1.5	2.4	3.3	4.2	7.1	
	School Databases	1.6 & 1.7	2.5 & 2.6	3.4 & 3.5	4.3 & 4.4	5.1 & 6.1	5.2 & 6.2

The SCSM was administered as a part of the Year Nine students' integrated studies, in which students are encouraged to merge their skills and ideas developed within separate subjects. Data concerning students' length of enrolment at the school, and the age of their computers, was collated from the school's databases.

Classroom observations took place in classes utilising technology to achieve a subject specific learning goal. Some of these classes were videotaped, allowing them to be studied in greater detail when considering the individual responses of students to set tasks, and the social interactions of the students. This process follows that described by Stoney and Oliver (1999).

8.4 DATA SOURCES

The main data source for this research was the Year Nine student cohort of an independent, metropolitan girls' school, providing a sample size of approximately 150 students. This school had been implementing a laptop program for nine years, in which all students in Years Five through to Year Ten use their notebooks across all learning areas, every day at school. The majority of students enrol in the junior years, although about one third of students begin in Years Seven and Eight, and approximately twelve students enrol in Year Nine. The Year Nine cohort consists of students that have had between one and five years exposure to the technology-rich learning environment. Closely associated with the Year Nine students are their teachers.

Teachers of the Year Nine students were also used as a data source. All staff are given a laptop computer when they are first appointed to the school. The computers are renewed every two or three years. Some students buy a new notebook computer every three years; others economise by keeping their original notebook computer for six years (Foord, 2005). Computer-based learning tools are developed by staff specific to their learning areas to complement commercially available software. Data about the length of enrolment at the school, and the age of their current notebook computer, are held within the school's databases.

8.5 DATA COLLECTION

The context for this study was determined by collecting data relevant to the research environment. This includes archival history of the development of the school and its technology program. Teacher interviews were conducted to provide a personal perspective of the use of technology across the curricula. Concurrently, the LoTI instrument (Moersch, 1999) was used to quantify the technology use within the school and therefore determine the level at which the school is operating, with respect to technology integration. The LoTI instrument, described in Chapter Five, is used to determine the level of computer efficiency of an institution. It draws on quantifiable data obtained through observations and structured interviews (Moersch, 2003). Introducing unstructured interviews allows the deeper exploration of teachers' responses (Punch, 2001), which can provide a better understanding of the technology-rich environment. Data pertaining to the age of the technology and its reliability were collated from existing school databases. Quantified data were compared with the teachers' perspectives to provide a deeper analysis of the teaching-learning environment.

8.5.1 Classroom Dynamics

The relationships that exist between the teachers and students, and the attitudes of the students towards computers, were determined by implementing three questionnaires. These are the QTI, CLEI and ACCC. Torrance (2001) recommended utilising technology when administering this type of instrument: "With these technologies you can perform in minutes what required months in 1958" (online). These instruments were digitised, and completed electronically, expediting their statistical analyses and reducing errors of translation. The 'logging-in' process to gain access to the questionnaires meant that, although students' responses remain anonymous, they could be collated by their User ID codes. This allowed individual student responses to be cross-referenced with other data. For example, the SCSM and/or ASCSC results.

Table 8.2

Description of the combined CLEI and ACCC scales

Scale	Extent to which …	Questions
Student Cohesiveness	…students know, help and support each other	1, -8, 16, 24, 31, -39, 47
Open Endedness	…computer activities emphasise an open-ended approach to learning	3, 10, 18, 25, 33, -41, 49
Integration	…computer activities are integrated with non-computer activities	-2, -5, -12, 19, 27, -35, 43
Technology Adequacy	…hardware and software is adequate for the tasks	4, -6, 13, 21, 29, 37, 44
Anxiety	…students feel nervous or uncomfortable using a computer	-7, -14, 20, 26, 32, 38, 45
Usefulness of Computers	…students believe computers are useful	-9, 15, -22, 28, 34, 40, 46
Enjoyment	…students enjoy using a computer	11, 17, 23, -30, 36, 42, -48

("-" indicates a reverse scored question)

The CLEI and ACCC were merged into one questionnaire that addresses the scales shown in Table 8.2. The merging process further separates the statements related to any one scale. This reduces the likelihood of students looking back at, and being influenced by, their previous answers. The amalgamation of the CLEI and ACCC is for administrative convenience only. Less disruption is caused to a school class by performing one survey rather than two separate surveys.

Newby stated that the CLEI was based on the *actual* version of the SLEI, originally developed by Fraser, Giddings, and McRobbie (1991, in Newby, 1998, online). The *actual* version asks students to respond with respect to their perceptions about their real learning environment. The predetermined validity and reliability of the SLEI allows for the direct transfer of four SLEI scales into the CLEI. Rule Clarity, considered less pertinent to a computing environment, was removed, and Technology Adequacy was added.

The utilisation of computers at the research site means that every classroom may be considered as a computer laboratory. For nine years students in Year Five through to Year Ten have been immersed in a culture of technology. Personal ownership of their computers means that questions such as "There are enough computers/terminals for students to use" and "'Outside my normal computer classes, I have to wait if I want to use a computer" (Newby, 1987, p. 2) become irrelevant. For this reason, the questions that relate to the scale Availability (originally called Material Environment) were removed.

Students in Year Nine undertake a compulsory course to develop their technology skills. Questions related to the usefulness of the computer course could steer the students to focus on this course. For these reasons the Usefulness of Course scale was omitted.

Many questions in both the CLEI and ACCC were reworded for clarity. For example, the double negative contained in question 46, "'I cannot imagine getting a job that does not involve computers" (Newby, 1987, p. 3), becomes "When I get a job I will not need to use a computer" and the scoring is reversed.

Given the modifications needed, it could be argued that a different instrument should have been used. For example, the original CCEI (Maor & Phillips, 1996) or the Web Based Learning Environment Inventory (WEBLEI) described by Chang and Fisher (2003) and Walker (2003). The CCEI was compiled over ten years ago. With respect to the development of computer use in schools, this is a long period of time. During this period many schools have integrated notebook computers with a 1:1 computer to staff/student ratio (Kessell, 2001). Any instrument written before this time will itself need considerable modification. The WEBLEI was developed to examine the delivery of online courses. It can be inferred from Chang and Fisher (2003) that, in this context, online environments are predominantly delivered via the Internet with the lecturer in absentia. It should also be noted that, like the CLEI, this tool was developed for use in the tertiary sector. Online learning environments at the secondary level are usually conducted with the teacher present. This introduces a dimension of teacher-student relationships that may affect the learning environment.

The ACCC and CLEI were administered during the first half of Term Three, 2006. This ensured that students new to the school in Semester One have had sufficient exposure to the school and classroom cultures to be able to form a valid opinion. Newby (1998) reported Cronbach reliability coefficients for the CLEI and ACCC as being 0.6 ~ 0.89 and 0.83 ~ 0.90 respectively. However, the modifications described above necessitate the coefficients to be re-determined. A pilot study using the modified questionnaire was conducted, prior to using the questionnaire with the research cohort.

Data pertaining to teacher-student relationships were collected by administering the QTI. Again, this instrument was digitised, but no changes were made to the original questions. Teaching staff clarified student questions as appropriate. The QTI was administered during the first half of Term Two, 2006. Again, this allowed new students to have assimilated the classroom culture. It also allowed teaching staff to use the QTI data as part of the reflective phase of their professional performance appraisal at their own discretion.

Classes in action were observed to provide a different perspective of teacher-student relationships, and to provide additional data regarding the tasks for which computer technology was employed. Lessons were videotaped during Terms One and Two, 2006, using a commercially available package to allow the statistical analysis of pre-determined events. Stoney and Oliver (1999) described a method of categorising instances of observed lower and higher order thinking, and examples of student dialogue commensurate with these categories. Instances were noted by viewing the videotapes after the conclusion of the lessons. This allows future statistical analysis; collating with other data sources; and it permitted the instances to be described in the context in which they occurred.

8.5.2 Technology Skills

The technology skills of students were determined from the externally marked ASCSC. The competition is designed to assess students' computer skills and knowledge outlined in the various State curricula. Students solve problems that involve navigating the Internet; operating systems software; designing web pages; using a word processor, spreadsheet and databases; programming; and designing networks. The questions presented in the ASCSC reflect the importance of the higher order thinking skills, and present an opportunity for students to perform a range of tasks using these skills. As the test is used in all Australian States and Territories, as well as in New Zealand and South East Asia, the content of the test papers is not based directly on any particular school curriculum. It is educed from the precepts on which curricula are constructed (Educational Assessment Australia, 2006).

The competition was divided into different age groups, and the groups have changed in successive years. In 2002 the test was divided into three broad groups referred to as Junior, Intermediate and Senior. By 2005 this had been replaced by a series of tests for Years 7/8, 9/10 and 11/12. In 2006 this series was further modified to provide individual tests for each year group up to Year Ten. The Year Nine test is set at a higher conceptual level than the test aimed at Years Seven and Eight. Questions are not repeated in successive years. These facts mean that it is difficult to compare results over successive years. While the validity of the test is not questioned, the internal reliability needs to be considered when interpreting the students' results. Students completed the 8/9 paper in May, 2005 and the 2006 paper in April, 2006.

8.5.3 Critical Thinking

Students' critical thinking skills were measured using the Ennis' Weir Critical Thinking Essay Test (EWCTET). Students received instructions on how to use the Reason!Able® software, described in Chapter Six, as a part of their Technology Skills classes. In February, 2006, students used this software to develop their test answers. Students completed the task individually, yet were free to discuss their work in progress with other students. This process was video taped and the students' dialogue was analysed to determine the extent to which higher order cognition occurred. The pre-determined marking key was used to judge their performance at scaffolding their answers.

8.5.4 Creative Thinking

Students' creative thinking was measured using the Scientific Creativity Structure Model (SCSM) instrument described in Chapter Six (Hu & Adey, 2002), with one change. Question Five, dividing a square into four equal parts, was replaced with an alternate question provided by Adey (pers. com., 10th October, 2005) that allows greater flexibility and originality.

The instrument requires students to produce creative solutions in written and diagrammatic form. This task was completed as a part of an integrated studies program during May, 2006. Some answers required a pictorial response, and so the test was completed as a paper and pencil exercise. This allowed students to focus on the creativity of their solutions without being sidetracked by the image editing features of software packages. Student responses to the questions were assessed using the SCSM marking guidelines.

Copies of the instruments used to collect data are found in the appendices.

8.5.5 Timings of Data Collection

Figure 8.1 summarises the times at which the various research instrument were applied.

It should be noted that one of the factors considered in this research is the relationship between the length of time students spend within the technology-rich culture and their performance measured by the above instruments. The instruments were administered at different times of the academic year, shown in Figure 8.1, and not all students completed each instrument on the same day. The Year Nine cohort consisted of seven separate classes with differing weekly timetables. Typically, it would take eight days for all students to have completed one instrument, and three terms to complete all instruments. For this reason it was necessary to calculate the students' length of time spent in the technology-rich environment at the time at which a particular instrument was used. Time spent in this environment was calculated from a student's day of enrolment up to the day a specific research instrument was administered.

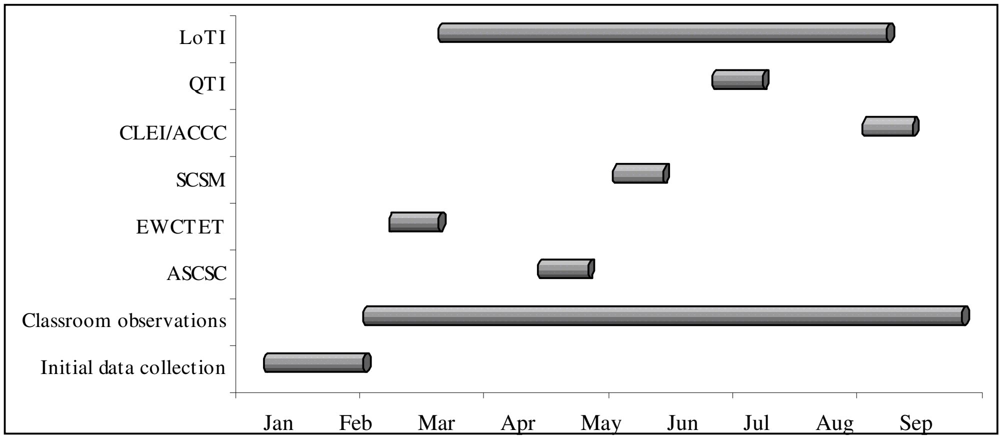


Figure 8.1. Administration of the research instruments throughout the teaching year.

8.6 DATA ANALYSIS

Analysis of the data was divided into two sections. The first section concerned analyses to determine the reliability of the instruments used, within the context of the research environment. Secondly, statistical analyses were conducted to establish the degrees of correlation between the sets of data. Where appropriate, both types of analysis were conducted on the sub-sets contained within specific instruments. For example, the different groups of computer skills assessed by the ASCSC; or the fluency, flexibility and originality sections of the SCSM.

The QTI, CLEI and ACCC provide individual students' perceptions of aspects of the learning environment measured on a five-point Lichert scale. The ASCSC, EWCTET and SCSM scores are converted to rankings. Preliminary analysis used a commercially available spreadsheet to format, group and graphically represent data, and to link the different data sources. Further statistical analysis was performed with SPSS software.

8.6.1 Reliability of the Research Instruments

Burns (1997) described four methods of determining reliability: Test-Retest; Alternate Forms; Split-Half; and Internal Consistency. As the name implies, the Test-Retest method requires students to be tested at different times, and the results of these tests are compared. The Alternate Forms approach involves administering two comparable (but different) tests to a study group and, again, comparing the results. The Split-Half method compares students' performances between the two halves of one test. A few factors precluded these methods from being adopted.

Data collection for this study was centred on normal classroom activities. The Test-Retest model would erode classroom time available for students to proceed with their curricula. The Alternate Forms method assumes that alternate forms for a given test exist. This is not the case for the QTI, CLEI, ACCC, EWCTET or the SCSM. The Split-Half method assumes that the test can be split into two equal halves, and that the split will produce two comparable sub-tests. While this may correct for the ASCSC, this test is composed of groups of questions, each addressing different areas of computer skills. In the interests of analysing students' responses to these scales, they must be kept intact. The QTI, CLEI and ACCC are composed of separate scales, each made up from five through to seven questions. These scales were then randomly assorted. It could not be assumed that the Split-Half technique would produce equivalent sub-tests. The EWCTET and SCSM also contain sub-scales, and consist of nine and seven questions respectively. The scales embedded within each question are marked by assessing students' responses. It is not practical to subject these instruments to the Split-Half method.

Reliability of the research instruments was determined using the Internal Consistency method. Specifically, by calculating Cronbach's alpha coefficient for each scale within a given instrument and, where applicable, for the complete instrument. This coefficient determines the degree of reliability between the answers to a group of questions that address a common theme (*Cronbach's coefficient alpha*, 2003).
Generally this coefficient will be between 0 and 1, although Nichols (1999) has described a situation in which a negative value can occur. The closer the calculated coefficient approaches 1, the more reliable the data can be considered.

8.6.2 Correlation Coefficients

Pearson's correlation coefficient requires both variables to be measured on an interval scale, and the coefficient is based on the real values. Spearman's rank coefficient does not assume that the intervals between the values are constant, simply that one value is greater (or lesser) than another (Burns, 1997). This is very often the case in tests given to students. It cannot be assumed, just because two questions are allocated one point each, that they are of equal difficulty. For this reason, Spearman's correlation coefficient was used.

8.7 SUMMARY

This chapter has presented the methodological primitives on which the research is based. Justification for the case study approach was outlined, as were the statistical techniques employed. Statistical tests were used to determine the reliability of the instruments used, as well as to answer the research questions. The questions have been presented as a series of null and alternative hypotheses. The null hypotheses do not imply that there is no relationship between two factors, rather they state that there is no relationship other than those occurring due to random chance.

The analyses of data fall into three main groups. Initially, the reliability of each instrument needs to be determined within the context of the research environment. Secondly, the extent to which the learning environment can be considered technology-rich needs to be identified. Finally, statistical analyses are required to test the hypotheses relevant to each research question.

Chapter Nine presents the results of reliability testing performed for the research instruments, and their associated discussion. Chapter 10 includes the qualitative and quantitative data used to establish the technological richness of the learning environment, and discussions of the data. Chapter 11 provides statistical analyses of the hypotheses derived from the research questions, shown in Chapters One and Eight. Results of the statistical analyses are discussed.

CHAPTER 9

RELIABILITY OF INSTRUMENTS

9.1 INTRODUCTION

In this chapter, data pertaining to the reliability of the research instruments are presented and discussed. In the interests of standardising the approach to assessing reliability, Cronbach's alpha coefficient is used wherever possible. The following sections address each of the instruments used for this research. Data used to determine the reliability of the instruments are presented and discussed. Conclusions about the reliability of the instruments within the research environment are given.

Data were collected from 150 Year Nine students in an independent, all-girls' school. The students, aged 14 and 15 years old, are either day students or boarders. Academically this group can be considered heterogenous. The group is skewed towards higher SES levels although it contains scholarship holders and other students from lower socio-economic backgrounds.

9.2 COMPUTER LEARNING ENVIRONMENT INVENTORY AND ATTITUDES TOWARDS COMPUTERS AND COMPUTER CLASSES

Editing of the questions, and the removal of specific scales, meant that a pilot implementation was necessary prior to using the instrument with the research cohort. This resulted with internal coefficients ranging from 0.36~0.74, shown in Table 9.1.

Data in Table 9.1 indicate that the individual scales of the CLEI instrument, are reliable. The Anxiety and Enjoyment scales of the ACCC are reliable but the Usefulness of Computers is suspect. Data in Table 9.2 indicate that the individual CLEI scales are reliable, with the exception of Integration. The individual scales of the ACCC are all reliable.

Table 9.1

Cronbach's Reliability Coefficients for the CLEI and ACCC (Pilot Data)

		Newby (1998)	McMahon (2005)		
Instrument	Scale	Alpha	Alpha	N Cases	N Items
CLEI	Student Cohesiveness	0.66	0.56	192	7
	Open-Endedness	0.60	0.53	122	7
	Integration	0.89	0.49	191	7
	Technology Adequacy	0.81	0.73	192	7
ACCC	Anxiety	0.90	0.66	190	7
	Enjoyment	0.90	0.74	185	7
	Usefulness of Computers	0.83	0.37	121	7

Table 9.2

Cronbach's Reliability Coefficients for the CLEI and ACCC (Research Cohort Data)

		McMahon (2005)		
Instrument	Scale	Alpha	N Cases	N Items
CLEI	Student Cohesiveness	0.65	115	7
	Open-Endedness	0.51	37	7
	Integration	0.38	117	7
	Technology Adequacy	0.76	118	7
ACCC	Anxiety	0.84	118	7
	Enjoyment	0.87	115	7
	Usefulness of Computers	0.67	109	7
	Enjoyment & Usefulness of Computers	0.84	105	28

Adapting the CLEI and ACCC for the secondary school environment included a pilot trial of the instruments. The internal consistencies in Table 9.1 appear low when compared with previous studies (Newby, 1998). Teaching staff commented that students found some of the questions irrelevant. For example, questions related to the usefulness of computers were greeted with mutterings such as “Of course they’re useful” and “This is dumb”. It should also be noted that the pilot test was conducted towards the end of the academic year. Students are generally tired and lacking their usual enthusiasm. With this mindset it is not unusual for students to simply answer all of the questions with little thought as to their responses. It was decided not to make any further adjustments to the survey questions.

Data from the research cohort, shown in Table 9.2 indicate that all of the ACCC and CLEI scales are reliable with the exception of Integration (alpha = 0.38). Several students asked for clarification of the Integration statements; for example, “I use the theory sessions during computer-based activities.” Stepwise removal of each Integration items produces the alpha coefficients shown in Table 9.3.

Table 9.3

Cronbach’s Reliability Coefficients for the CLEI Integration Scale

Item Removed	Alpha Coefficient	N Cases	N Items
2	0.27	117	6
5	0.42	117	6
12	0.27	117	6
19	0.34	117	6
27	0.37	119	6
35	0.34	117	6
43	0.41	120	6

Removal of specific items does not significantly change the reliability of this aspect of the CLEI instrument. Conclusions pertaining only to the Integration scale should be treated with caution.

9.3 AUSTRALIAN SCHOOLS COMPUTER SKILLS COMPETITION

This test is set annually by the University of New South Wales. In 2005 the student cohort sat this test as part of their Technology Skills academic program. The test consists of 45 multiple choice and short answer questions that test students in an array of computing skills. The scales within this array, and their internal reliability, are shown in Table 9.4.

All of the Cronbach reliability coefficients are 0.55 or greater, which indicates that the Australian Schools Computer Skills Competition (2005) provides a reliable means of measuring students’ computer skills.

Table 9.4

Cronbach’s Reliability Coefficients for the 2005 ASCSC

Scale	Alpha	N Cases	N Items
Productivity Tools	0.55	129	11
Internet	0.63	129	5
Communications	0.62	112	7
Hardware	0.66	105	5
Software	0.60	127	12
Programming	0.70	105	5

Table 9.4 shows reliability factors ranging from 0.55 through to 0.70 for components of the complete test. All components other than Productivity Tools are equal to, or greater than, 0.60. Stepwise removal of each Productivity Tools questions produces the alpha coefficients shown in Table 9.5.

Table 9.5

Cronbach's Reliability Coefficients for Productivity Tools

Question Removed	Alpha	N Cases	N Items
5	0.55	129	10
6	0.56	129	10
7	0.55	129	10
8	0.54	129	10
13	0.52	129	10
14	0.53	129	10
19	0.53	129	10
20	0.53	129	10
21	0.57	132	10
25	0.52	130	10
26	0.53	129	10

Removing Question Six or Question 21 results in a slight increase in reliability. Removal of any other questions results in a lower reliability coefficient. Consequently, all questions were maintained for this scale. The Productivity Tools scale measures the students' skills with packages such as word-processors or spreadsheets. According to Jonassen (1996) this represents the lower order cognitive use of computers, as demonstrated in Figure 9.1 (Educational Assessment Australia, 2005).

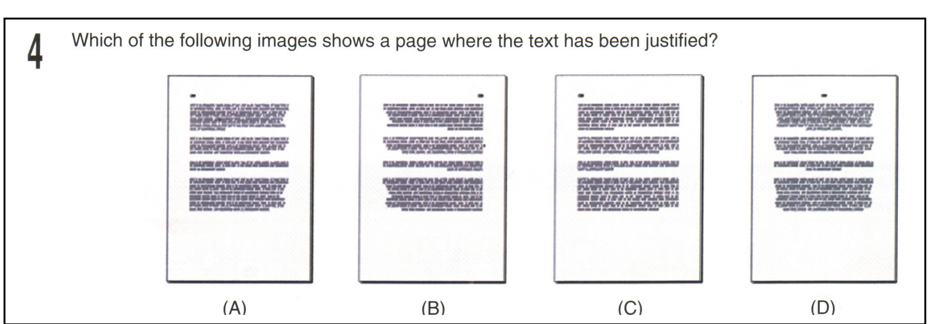


Figure 9.1. Lower Order Cognition (Productivity Tool)

Such a question requires a student to recognise the different ways of formatting text, indicative of the *remembering* or *understanding* levels described by Anderson and Krathwohl (1996). Similar low order questions are evident within the other scales, such as the *communications* scale shown in Figure 9.2 (Education Assessment Australia, 2005).

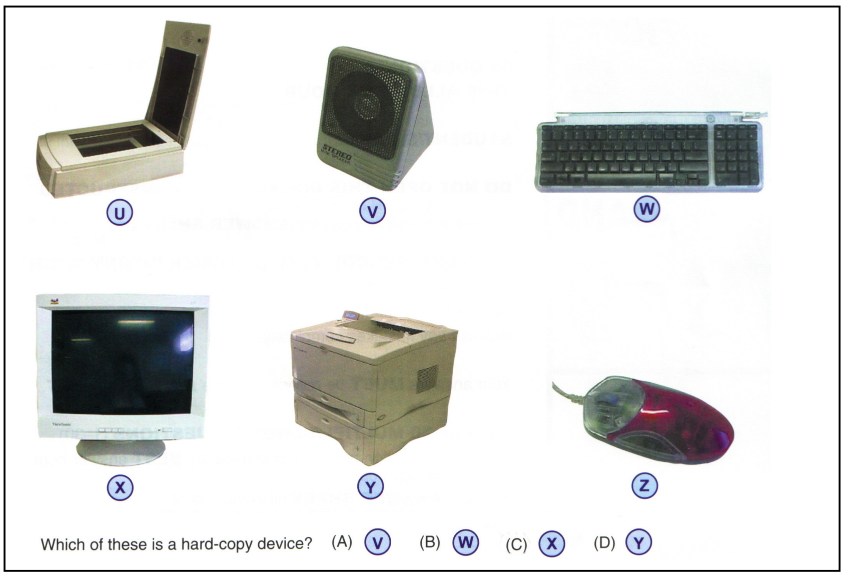


Figure 9.2. Lower Order Cognition (Hardware).

The lower degree of reliability apportioned to the Productivity Tool scale is offset by the greater reliability demonstrated by the other lower order scales.

9.4 QUESTIONNAIRE ON TEACHER INTERACTIONS

The QTI consists of eight scales that measure different, but related, aspect of teacher-student relationships. Each scale contains six questions. The reliability coefficients for these scales are shown in Table 9.6.

Data in Table 9.6 indicate that the scales are reliable within this research cohort. The range of reliability coefficients for this study (0.58-0.81) coincide with those of earlier researchers (0.59-0.96) shown in Table 5.3

Table 9.6

Cronbach's Reliability Coefficients for the QTI

Scale	Alpha	N Cases	N Items
Admonishing	0.76	133	6
Dissatisfaction	0.80	139	6
Helping / Friendly	0.81	135	6
Leadership	0.77	138	6
Student Responsibility	0.58	138	6
Strict	0.73	139	6
Uncertainty	0.69	139	6
Understanding	0.72	137	6

Table 9.6 indicates reliable data for all of the QTI scales. The lowest coefficient is for Student Responsibility (0.58). Stepwise removal of each question for Student Responsibility and the resulting alpha coefficients are shown in Table 9.7.

Table 9.7

Cronbach's Reliability Coefficients for Student Responsibility

Item Removed	Alpha Coefficient	N Cases
26	0.59	139
30	0.52	138
34	0.55	139
38	0.49	138
42	0.51	138
46	0.52	138

N items = 5

In all but one case (Item 26) the removal of each item reduced the reliability coefficient. Removing Item 26 resulted in a marginal increase, so all items were maintained for this scale. Each scale of the QTI is diametrically opposed to one other scale (for example, Leadership vs Uncertainty) and so an overall alpha coefficient cannot be determined. The correlations of each scale with each other scales are shown in Table 9.8.

Table 9.8

Pearson's Correlations for the QTI Scales

	Leadership	Helping Friendly	Understanding	Student Responsibility	Uncertain	Dissatisfied	Admonishing	Strict
Leadership	1.000	0.681**	0.792**	0.032	-0.483**	-0.409**	-0.420**	-0.344**
Helping Friendly		1.000	0.713**	0.335**	-0.392**	-0.530**	-0.500**	-0.500**
Understanding			1.000	0.162	-0.453**	-0.547**	-0.539**	-0.466**
Student Responsibility				1.000	0.273**	-0.097	0.072	-0.338**
Uncertain					1.000	0.353**	0.496**	0.202**
Dissatisfied						1.000	0.596**	0.583**
Admonishing							1.000	0.499**
Strict								1.000

*Correlation is significant at the 0.05 level (2-tailed) **Correlation is significant at the 0.01 level (2-tailed)
N = 141

The data in Table 9.8 demonstrate significant correlations, positive and negative between the eight scales. This reinforces the circumplex nature of the QTI, as shown in Figures 9.3 and 9.4.

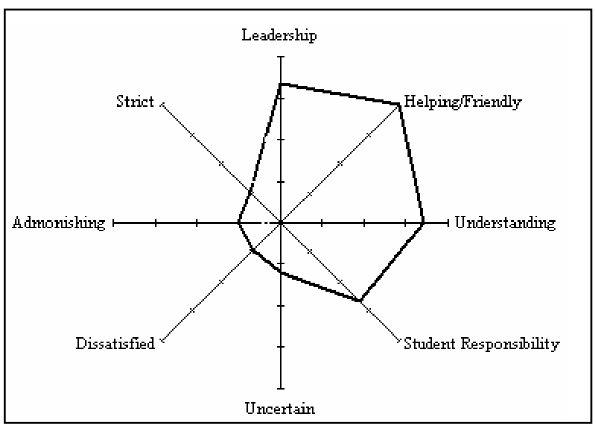


Figure 9.3. Circumplexion within the QTI (Helping/Friendly).

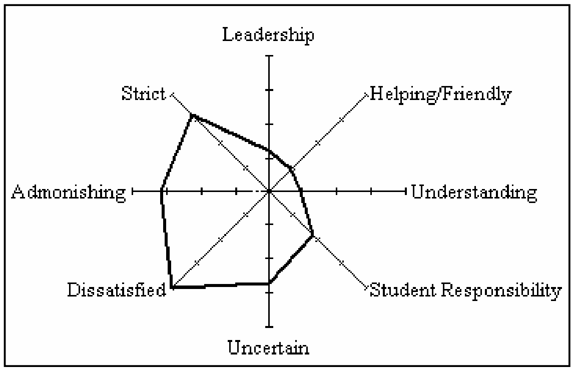


Figure 9.4. Circumplexion within the QTI (Dissatisfied).

Figures 10.9 and 10.10 show that the scales closest to each other are positively related; those in opposition show a negative relationship; and those which are orthogonal show little positive or negative relationships. Tables 9.12, 10.11, 10.12, and Figures 10.9 and 10.10 indicate that the results for the QTI administered within this research environment are reliable.

9.5 ENNIS-WEIR CRITICAL THINKING ESSAY TEST

Each question assesses a different aspect of critical thinking. The exceptions are questions three and eight, which both determine the students' ability to recognise a correct argument. The correlations between student performance for each question and their total scores are shown in Table 9.9. These results are supported by Cronbach's alpha coefficient for the nine questions, which was 0.66. The coefficients in Table 9.9 demonstrate that the data obtained from the EWCTET are reliable.

The EWCTET consists of eight responses to seven aspects of an argument, and a summary response. Only Paragraphs Three and Eight within the EWCTET (shown in Appendix Two) address the same concept. The scales used in the EWCTET, described in Table 9.9, are not in common use, although they are considered valid by Ennis (1998). Consequently, internal reliability by means of calculating a series of Cronbach alpha coefficients cannot be achieved. Reliability was determined by calculating Spearman's correlation coefficient between each response and the total score. Data in Table 9.9 demonstrate significant correlations between each response and the total score. These coefficients, and Cronbach's alpha coefficient for the overall test, indicate internal reliability for the EWCTET.

Table 9.9

Spearman's Correlations for the EWCTET

		EWCTET Total Score	
Question Number	Q1 Recognise misuse of analogy	Rho	0.471**
		N	122
	Q2 Recognise irrelevance of argument	Rho	0.388**
		N	118
	Q3,8 Recognise correct argument	Rho	0.604**
		N	117
	Q4 Recognise circular argument	Rho	0.648**
		N	82
	Q5 Recognise alternative arguments	Rho	0.556**
		N	101
	Q6 Recognise lack of controls and/or poor sampling	Rho	0.657**
		N	106
	Q7 Recognise incorrectly asserted definition	Rho	0.661**
		N	78
	Q9 Quality of summary of overall argument	Rho	0.535**
		N	110
	EWCTET Total Score	Rho	1.000
		N	131

**Correlation is significant at the 0.01 level .

9.6 SCIENTIFIC CREATIVE STRUCTURE MODEL

The SCSM measures student's creative thinking within the scientific domain. Seven questions measure three scales of creativity – Fluency, Flexibility and Originality. The seven questions address different aspects of science: knowledge; problem-solving; technical development; imagination; experimental design; and product design. Each question was designed to measure at least two of the creativity scales. FReliability coefficients were determined for these scientific aspects and the creative thinking scales. These coefficients are shown in Tables 9.10 and 9.11.

Table 9.10

Cronbach's Reliability Coefficients for Three Scales of Creative Thinking

Scale	Cronbach's alpha coefficient	N Items
Fluency	0.80	4
Flexibility	0.47	7
Originality	0.44	7

N = 150

Table 9.11

Cronbach's Reliability Coefficients for Creative Thinking

Scientific Context	Cronbach's alpha coefficient		
	Hu & Adey (2002)	McMahon (2006)	N Items
Q1 Science Knowledge	0.76	0.80	3
Q2 Sensitivity to Scientific Problems	0.73	0.77	3
Q3 Technical Production	0.74	0.89	3
Q4 Scientific Imagination	0.77	0.91	3
Q5 Problem Solving	0.58	0.88	2
Q6 Experimental Design	0.63	0.34	2
Q7 Technical Production	0.73	-0.04	2
Complete Test Paper	0.89	0.81	18

N = 150

Table 9.10 demonstrates that the data for the fluency aspect of creative thinking are reliable; flexibility and originality appear unreliable. Each question shown in Table 9.11 measures at least two of the three creativity scales. Table 9.11 demonstrates that the data obtained from questions one through to five is reliable; students were consistent with their responses to the different scales within each question. Data for questions six and seven cannot be considered reliable for this research cohort. Excluding questions five, six and seven increases the flexibility and fluency alpha coefficients to 0.78 and 0.58 respectively, and increases the overall alpha coefficient to 0.81. For the purposes of testing the hypotheses (Chapter 11), only data from questions one, two, three and four were used.

Hu and Adey (2002) reported a Cronbach reliability coefficient of 0.89 for the complete test, compared to 0.63 reported for this research. Both coefficients indicate that the test is reliable. The low coefficients pertaining to Question Six and Question Seven are partly responsible for the lower overall alpha coefficient. Removing these questions increases Cronbach's alpha coefficient to 0.65 for the overall test.

Question Five asks students to divide a square into four equal areas in as many ways as possible. In fact, there are only four distinct solutions, with many variations of lines that centrally cross – straight lines that produce triangles; curved lines that produce trilaterals; and zigzagged lines that produce polygons, the number of sides of which are determined by the sharpness of the drawing instrument. While this leads to a great deal of fluency, the scales of flexibility and originality are limited. However, fluency is not measured by this question. Replacing this question with an alternative supplied by the original authors (Adey, 2005) increased the possibility of higher scores for flexibility and originality.

Only Questions One, Two, Three and Four contain all three of the fluency, flexibility and originality scales. By excluding Questions Five, Six and Seven the reliability coefficients for flexibility and originality increase to 0.78 and 0.58 respectively. The alpha coefficient for the test increases to 0.78.

9.7 SUMMARY

The instruments discussed in this chapter have been shown to be reliable within this research environment. The ACCC and CLEI measure related aspect of students' perceptions, all of which are shown to be reliable when considered together. The Integration component of the CLEI needs to be treated with caution for this research cohort. There is perhaps a need to develop a new instrument, based on the ACCC and CLEI, specifically for use in notebook based secondary schools.

The circumplex nature of the QTI has been confirmed. Radar plots were easily constructed and are appropriate for individual teachers who wish to administer the QTI on a small-scale basis.

The EWCTET produced reliable data when completed using argument-mapping software. The relatively new SCSM was shown to be reliable when data for Fluency, Flexibility and Originality are considered within specific aspects of science, namely scientific knowledge, problem solving, production and applying scientific imagination.

CHAPTER 10

TECHNOLOGY-RICH LEARNING ENVIRONMENT

10.1 INTRODUCTION

In Chapter Five, instruments that can be used to study the learning environment are described. Fraser (2001) argued that the environment has a significant effect on student learning. This chapter describes the socio-cultural history of the learning environment in which the research was based. The extent to which technology is implemented was determined by using the LoTI instrument described earlier, allowing qualitative aspects of the environment to be quantified.

10.1.1 Socio-cultural Background

The technology-rich learning environment in which this research is based is embedded in an independent, all girls' school. Affiliated with the Uniting Church, the school accepts day students and boarders. The student population ranges from kindergarten through to Year 12 (Laurie, 2003). The Junior School caters for students in Kindergarten through to Year 6; Middle School consists of Years 7, 8 and 9; the Senior School is comprised of Years 10, 11 and 12. With tuition fees that range from $8,000 to $11,000, the College generally attracts families that place a high value on education and are committed to academia.

In 1996, the Information and Communication Technology Committee of the school recommended to the Board that, to support the educational benefits of technology, the College needs to increase student access to, and use of, computers within the context of the curriculum. This would require ownership of computer by the students, with the school providing the network infrastructure, technical support and software (Kessell, 2001).

These recommendations led to the implementation of a notebook program, in which all staff and all students in Year Five through to Year Ten use notebook computers and associated technology during the teaching/learning process. This program supports the development of student-centred, constructivist learning environments by giving students greater autonomy in their learning.

The notebook program was founded on the belief that information and communications technology empowers students. The portability of notebook computers allows students to determine what, where, how and when learning will take place (Rixon, 2001). By moving beyond the basic aspects of learning, notebook technology allows students to engage in multi-dimensional learning rather than just “taking notes”. This approach reflects the position of Solomon (1993) and Jonassen (1996), who propose that technology addresses two cognitive levels. By taking care of lower order levels such as knowledge recall, computers allow learners to focus on higher order activities. The multi-dimensional approach enables students to use technology to develop and process higher order thinking.

Three years after the introduction of the notebook program an external evaluator was contracted to evaluate the success of the program and to suggest directions in which the program should develop (Kessell, 2001).

The review was conducted over a three-year period from 1998 to 2000. Data were collected by questionnaires given to teachers, students and parents and by interviews (Kessell, 2001). The results of this review are quite polarised. In the junior classes (Years Five and Six) students, staff and parents comment favourably on the effect the notebook program has had on learning. Higher grades (Years Seven through to Ten) are quite scathing, as summarised by one student:

> *Rip off. too much trouble. costs too much. brake [sic] too much. I find that I do better in subjects that don't use CD ROMs or laptops to teach ie. I did better in Gentics [sic] than Physics. Get rid of compulsory laptops* (Kessell, 2001, online).

One hundred and forty three Year 10 students completed the questionnaire, of which 136 added written comments. Only two per cent made positive comments and 98% were highly critical of the notebook program. Some staff and parents expressed concerns about the quality of the research. For example, three parents responded with the following (comments in square brackets are those of Kessell, 2001):

> *We have answered this survey in light of how we feel about the laptop program as it stands today. This survey we feel is not objectionable* [meant to say objective ??]. *The questions asked do not address the real concerns of parents. They do not delve below the surface to get any real answers and unless one writes as I am now doing, the survey results will not give a true reflection of our concerns.*
>
> *There are some useless/silly questions ie question 8, 9 and 19 which can only be answered positively and makes one feel that a positive result is all this survey is aiming for.*
>
> *Most of the other questions do not address the laptop issue.* (Kessell, 2001, online).

The final remarks are left to two families, which illustrate the polarisation of this issue, exemplifying the concerns initially described in Chapter One, Table 1.2:

> *Either get your act together as a school and use this technology properly and efficiently as it has huge potential - or get rid of it.*
>
> *The College should be extremely proud of its accomplishments in Years 5 and 6. Well done!* (Kessell, 2001, online)

10.1.2 Present Day Environment

It became clear that successful integration of notebook technology across and within learning areas requires specific skills to be taught to staff and students; support provided to staff and students; and the correct use of the College network. The Kessell Report, and the unfortunate death of the incumbent Head of Computing, initiated significant changes in the administration, infrastructure and teaching related to technology in the College. The Learning Technologies department was formed to instigate and integrate these changes. The Department is responsible for providing student and staff development within the realm of technology and its application to teaching and learning. The more pertinent changes included:

- Employing a Head of Department to oversee the notebook program and professional development of academic staff;
- Restructuring the middle school technology teaching program;
- Integrating learning activities with other academic subjects;
- Professional Development for academic staff;
- Redesigning the network to allow external access to the school's resources via the Internet;
- Upgrading the network infrastructure; and
- Upgrading personal hardware and software.

Early model notebook computers could only attach via network cables and had a three-hour battery life. This often resulted in a spaghetti configuration of cables and power leads in a classroom. In addition to potential Occupational Health and Safety issues, setting up and dismantling the network at the start and end of each lesson eroded the available teaching time in the Middle School classes. Between 2003 and 2005 the network was modified to allow wireless connections, and wireless cards were integrated with the notebooks.

Access to school resources have been made available through a password protected Extranet, allowing student access from any globally available Internet connection. In addition to teaching and learning resources, College email is also available via the Internet. Assignments are created, delivered to students, collected and collated electronically via Microsoft Class Server®. The combination of these changes means that students can receive, complete and hand in assignments from home, or any place in the world that provides Internet access.

All Middle School students are enrolled in a Technology Skills program that addresses the Technology and Enterprise outcomes, specifically the *Technology Process* and *Technology Skills* (Themby & Jeffrey, 2005). Whilst there are other outcomes within this learning area of equal value, the program is subject to timetabling constraints. The course focuses on outcomes that have the most application to other learning areas.

The program is based on the Cognitive Flexibility Theory described by Spiro (1991). Cognitive flexibility enhances the attainment of knowledge in learning environments that require the integration of cognitive processes from different perspectives. Consequently, this program provides students with the technical and organisational skills necessary to effectively use their laptop in all learning areas.

Skills are initially presented through electronic or teacher-led tutorials, during which students work in small groups and/or independently on related tasks. The acquisition of these skills by students is determined through a range of assessment items that integrate with their learning in other curriculum areas. Rubrics that detail what is required by students to demonstrate a particular level are provided to students. The nature of the tasks is open-ended, which allows students to achieve a level higher than the focus of the assignment.

Teachers from different learning areas were asked to describe the use of technology within their subjects. Their answers can be divided into using technology as a productivity tool and as a mindtool. A summary or these responses is shown in Table 10.1.

These data points towards technology being used across a wide range of learning areas as both a productivity tool and as a mindtool, described by Jonassen (1996) in Chapter Four. The extent to which technology is used is further revealed by specific teacher responses ("Technology @ Penrhos", 2005):

> *Enthusiasm for technology in the classroom has increased over the years, because it allows you to go beyond the classroom – beyond the paper and pencils*
>
> *Phys Ed may be one of the areas where you would think we are not suited to technology when in fact we make extensive use … of the technology*

The girls are excited by the real-life context of their work, including budgeting aspects of art production

Computers allow students to have experiences that they couldn't otherwise have.

Table 10.1

Computer Use in Different Curricula Areas

Learning Area	Computer Use Productivity tool	Mindtool
Art	Net searching	Create individual artwork
LOTE	Voices embedded into documents	Students become more critical of their written & oral work. Students make connections between LOTE and English
English	Summarise group activities	Improves logic. Essay structure improves as students critically manipulate text.
Mathematics	Skill building	Students have the freedom & responsibility to explore mathematics.
SOSE	Technology skills applied to SOSE	Concept mapping
Phys Ed	Enhances students' presentation tasks	Metacognitive reflection on learning
Science	Quick data gathering	Selecting/filtering relevant data

Tables 10.3 and 10.5 (shown in Section 10.2.1) indicate that technology is used widely throughout the school, and at different cognitive levels. There appears to be a degree of trepidation in some learning areas, due in part to teachers not believing that they have the necessary computer skills to use technology in their subject area. For example, one teacher stated:

The use of technology in the classroom requires a hell of a lot of courage given that the students generally have greater technical skills, so they will not see you as the expert.

Many teachers did not feel comfortable with the idea that their students know more about a particular subject, or have better skills, than themselves. Another concern is that without the necessary computer skills the teacher cannot design a lesson that uses the technology effectively. However, in this particular environment the teachers do not need to be able to teach the computer skills, as the above teacher went on to say:

> *This is supported by technology support group who will provide the girls with the necessary skills, without the specialist teacher needing to learn those skills.*

Several staff commented on the advantages of this approach, which allows them to focus on developing higher order activities, based on the existing productivity skills of the students:

> *It's much more driven by them [students], and I find that, you know, they internalise, you know, those areas much more quickly than what they used to before.*
>
> *Technology gives the flexibility to the students to ask the 'what if' questions – to really explore the higher order thinking. To ask questions and to be building their own learning.*

10.2 LEVEL OF TECHNOLOGY IMPLEMENTATION

10.2.1 Results

The levels of technology implementation identified by Moersch (1999, p. 41) are described in Chapter Five. The pedagogy apparent within each level is shown in Table 10.2 (Moersch, 1995).

Table 10.2

Description of LoTI Levels

Level	Pedagogy
0	Traditional methods/ materials. Little or no computer use
1	Technology based instruction is predominately about the technology
2	Teacher directed instruction; technology use is peripheral or dispensable
3	Teacher directed instruction; technology use is adapted to fit with traditional goals
4	Constructivist instruction; technology is used for collaborative instruction
5	Constructivist instruction; students & teachers are learners; technology supports self directed, collaborative learning
6	Constructivist instruction; students & teachers are learners and researchers; technology supports self directed, collaborative learning

Data collated from a 2005 survey of staff indicate the range of cognitive activities undertaken by students when using technology across all eight learning areas. The associations between the cognitive activities and the LoTI levels were determined by interpreting the intent of the cognitive activity description and matching them to the appropriate LoTI level. These cognitive activities, and the LoTI level to which they are ascribed, are shown in Table 10.3. The percentage of class time in which computers were not used was determined from classroom observations of students. This time includes the introductory and the concluding stages of lessons, teacher-led phases and disengaged students.

The data were supplemented by classroom observations conducted by the researcher during March through to July, 2006. As the survey was conducted in November, 2005, all of the LoTI related data were collected within a nine month period. Pedagogical changes during this time are minimal and the two sets of data allow the LoTi efficiency to be calculated from different perspectives.

Table 10.3

Summary of Computer-based Cognitive Activities

Activity	LoTI Category	Number of Responses N	%	Class Time %
Non-use	0			33.33
Develop and use traditional literacy skills.	1	22	5.2	3.47
Develop and use traditional numeracy skills.	1	9	2.1	1.40
Develop an understanding of the role of computers in the learning process.	2	10	2.4	1.60
Locate, record, organise and manipulate information.	2	28	6.6	4.40
Undertake formative and/or summative assessment.	2	16	3.8	2.53
Demonstrate what they have learned.	3	30	7.1	4.73
Develop competencies within a specific curriculum area.	3	19	4.5	3.00
Engage in sustained involvement with curriculum activities.	3	20	4.7	3.13
Provide motivation for curriculum tasks.	3	27	6.4	4.27
Construct knowledge.	4	24	5.7	3.80
Develop literacy across curriculum areas.	4	15	3.5	2.33
Integrate different media to create appropriate products.	4	19	4.5	3.00
Support their learning according to their individual needs.	4	18	4.2	2.80
Undertake self-directed projects.	4	19	4.5	3.00
Work collaboratively with their peers.	4	23	5.4	3.60
Acquire a deep knowledge/understanding in a specific curriculum area.	5	9	2.1	1.40
Critically interpret information and evaluate the worth of this information.	5	16	3.8	2.53
Explore their own, and societies, values.	5	11	2.6	1.73
Facilitate risk-taking.	5	12	2.8	1.87
Reflect on their learning processes.	5	17	4.0	2.67
Solve authentic problem that require integration of curriculum areas and relate to prior knowledge.	5	12	2.8	1.87
Acquire deep knowledge/understanding about a particular topic.	6	26	6.1	4.07
Synthesise their knowledge.	6	22	5.2	3.47
Total		424	100.0	100.00

The LoTI levels provide an indication of technology implementation as described in Table 10.2. Matching actual classroom activities to the theoretical levels is achieved by observing and recording classroom activities. Descriptions of the activities indicative of a particular LoTI level are shown in Table 10.4 (Moersch, 1999). Each LoTi level has a range of descriptors coded by letters (E.G. 1A, 1B, etc), and a written interpretation for each descriptor. This should be referred to when examining the data presented in Table 10.5.

Table 10.4

Descriptors of Student Activity for Different Levels of LoTI

Level	Code	Description
0	0A	Technology is not in use.
	0B	Materials are traditional and predominately text-based
1	1A	A person other than the teacher delivers instruction using technology
	1B	Technology use has little relevance to the overall instructional
	1C	The main goal of the lesson is to acquire technical skills separate from academic goals
	1D	Technology use is separate from the learning focus
	1E	Technology use occurs only at scheduled times; access is limited beyond the schedule
	1F	Available classroom computers are used exclusively for teacher productivity
	1G	Multimedia applications are used to embellish classroom lectures or teacher presentations
	1H	Curriculum tools are used extensively to generate standards-driven lesson plans
2	2A	Student discussions, & projects are focused on the technology, not the content
	2B	Student work is focussed on developing technology skills, learning doesn't drive the technology use.
	2C	Technology is used mainly for extension activities or enrichment exercises
	2D	Technology is used for low level cognitive tasks related to specific, learning goals
	2E	Student work produced using technology requires little analysis or individual creativity
	2F	Technology tasks are simplistic and use a "cookie cutter" approach to what is required
	2G	The main purpose for using technology is to sustain interest, not to develop concepts or content skills
	2H	Technology's role in the learning activity is disjointed, uneven, or uncertain
	2I	Use of technology seems optional and unnecessary to achieve learning goals
3	3A	Productivity tools are used primarily for analysing information, making inferences, and drawing conclusions from an investigation
	3B	Students are involved with different forms of web-based projects that require them to research information, draw conclusions and incorporate them into some form of multimedia presentation
	3C	The web is used for research purposes or to interact with selected software applications that require students to take a position or role play an issue
	3D	Technology is used for higher cognitive tasks related to specific learning goals
	3E	Technology is used to enhance alternative assessment schemes that demonstrate higher cognitive skills
	3F	Technology provides adaptations in activities, assessments, & materials for special populations
4	4A	Teachers can readily design and implement learning experiences that empower students to identify and solve authentic problems relating to an overall concept using technology with little assistance
	4B	Technology is used as a tool to help students identify and solve authentic problems relating to an overall concept; the teacher is confident and comfortable with using technology in this context

	4C	Emphasis is placed on authentic problem-solving, and/or on issues that require higher levels of cognitive processing and in-depth examination of the content; the teacher has the background and confidence to nurture this strategy
	4D	Technology use encourages and enables student choice and decision-making during instruction
	4E	Technology use promotes collaboration among students directed at authentic problem-solving, issues resolution, and/or student action
	4F	Students use a variety of technologies in assessment activities to show evidence of understanding relating to an authentic performance task
5	5A	Technology extends the classroom by expanding student experiences and collaboration beyond the school and local community
	5B	Collaborative learning experiences involving other schools, research institutions, etc, to expand student experiences in problem-solving and student activism surrounding a major concept
	5C	Students initiate using technology appropriately for self-directed learning and assessment, including for portfolios. Students select and use technology to investigate topics, to create original products, to communicate knowledge, and to demonstrate mastery of complex skills and concepts
	5D	The complexity and sophistication of the technology used are commensurate with (1) the teacher's experiential-based approach to teaching and learning & (2) the students' level of complex thinking of the content experienced in the classroom
6	6A	Technology is a seamless tool used by students through their own initiative to find solutions related to an identified "real-world" problem.
	6B	Students and teachers have ready access to, and a complete understanding of, a vast array of technology-based tools to accomplish any particular task at school
	6C	The instructional curriculum is entirely learner-based. The content emerges based on the needs of the learner according to his/her interests, needs, and/or aspirations, and is supported by unlimited access to the most current computer applications and infrastructure
	6D	Students seek innovative ways to incorporate new uses of technology into their learning experiences & develop new technology skills as needed for self-directed, purposeful projects

Teachers across all eight learning areas were asked if their classes could be observed, and computer activities recorded. The descriptions outlined in Table 10.4 were recorded as either having occurred or not occurred. The actual number of occurrences was not recorded as this could be influenced by the number of students in any given class. Classroom observations of these activities are shown in Table 10.5.

Table 10.5

LoTI Observations within classes

LoTI Category		Class								Total		Class Time
Level	Code	1	2	3	4	5	6	7	8	N	%	%
0	0A											
	0B											33.33
1	1A						✓			1	1.15	
	1B											
	1C											
	1D											
	1E											
	1F											
	1G											
	1H											0.77
2	2A						✓			1		
	2B			✓						1		
	2C				✓		✓			2		
	2D						✓			1	5.75	
	2E											
	2F											
	2G											
	2H											
	2I											3.83
3	3A			✓				✓	✓	3		
	3B								✓	1		
	3C		✓	✓					✓	3		
	3D		✓	✓	✓			✓		4		
	3E			✓	✓				✓	3		
	3F		✓		✓		✓		✓	4	20.69	13.79
4	4A	✓			✓	✓		✓	✓	5		
	4B	✓	✓	✓	✓	✓		✓	✓	7		
	4C	✓	✓	✓	✓	✓		✓	✓	7		
	4D	✓	✓	✓	✓	✓		✓	✓	7		
	4E	✓	✓			✓	✓	✓	✓	6		
	4F	✓		✓	✓	✓			✓	5	42.53	28.35
5	5A					✓				2		
	5B		✓							2		
	5C	✓			✓	✓			✓	4		
	5D	✓				✓			✓	3	12.64	8.43
6	6A	✓	✓		✓	✓				4		
	6B	✓	✓	✓	✓	✓			✓	6		
	6C					✓				1		
	6D			✓	✓	✓			✓	4	17.24	11.50

Data from Table 10.4, in conjunction with that in Table 10.5, were used to estimate the percentage of students' computer time spent in each of the levels described by Moersch (1999). Classroom time in which computers were not used was determined from classroom observations based on 65 minute lessons. The percentage figures from Tables 9.3 and 9.4 are re-expressed as percentages of class time. They are shown in Table 10.6, together with the overall technology implementation efficiency ratings. Columns C_i and D_i are derived from Table 10.4; columns C_{ii} and D_{ii} from Table 10.5.

Table 10.6

LoTI Computer Efficiency Rating Chart

Descriptor	Level	Learner Use %		No. of Computers		Product (B*C*D)/100	
A	B	C_i	C_{ii}	D_i	D_{ii}	E_i	E_{ii}
Non-use	0	33.33	33.33	291	25	0.00	0.00
Awareness	1	4.87	0.77	291	25	14.17	0.19
Exploration	2	8.53	3.83	291	25	49.64	1.92
Infusion	3	15.13	13.79	291	25	132.08	10.34
Integration	4	18.53	28.35	291	25	215.69	28.35
Expansion	5	12.07	8.43	291	25	175.62	10.54
Refinement	6	7.54	11.50	291	25	131.65	17.25
Total		100.00	100.00			718.85	68.59
F_i	718.85/(291*4) = 0.62			Computer Efficiency Rating = 62%			
F_{ii}	68.59/(25*4) = 0.68			Computer Efficiency Rating = 68%			

The data in Table 10.6 indicate that technology is predominantly used at Levels Four and Five, as measured by the LoTI scale, which suggests an emphasis on lessons that implement technology used across the learning areas to address higher orders of learning.

10.2.2 Discussion of Results

Assessing the level of technology implementation is not an exact science. Classroom observations require the approval of the teacher. Within an environment that promotes technology, there could be some reluctance to allow observations in a classroom that may not promote technology integration. Those teachers that readily accept observations of their lessons are likely to be those who confidently and gainfully employ technology in their classes.

To address this predicament, data for the LoTI evaluation were collected by two methods. Staff completed an anonymous survey in which they indicated the types of activities that were occurring in their classes. These were then equated with the LoTI descriptors. First hand data were gained from classroom observations across eight learning areas. LoTI efficiency ratings were then calculated based on both sets of data. While there is no statistical test that can be used to determine the significance of this data, the two calculated efficiency ratings of 68% and 62%, shown in Table 10.6, are close, which suggests that these approaches are reliable. The efficiency rating between 60% and 70% indicates a high level of computer integration across the learning areas.

10.3 STUDENT PERCEPTIONS OF THE TECHNOLOGY-RICH LEARNING ENVIRONMENT

10.3.1 Results

Student perceptions were determined from the data presented in the CLEI, ACCC and QTI. Each measures different aspects of the students' attitudes towards the learning environment. The CLEI and ACCC, administered together, provide data about students' perceptions of technological aspects of the learning environment, and data about their attitudes towards the technology. The mean responses to these surveys are shown in Figure 10.1.

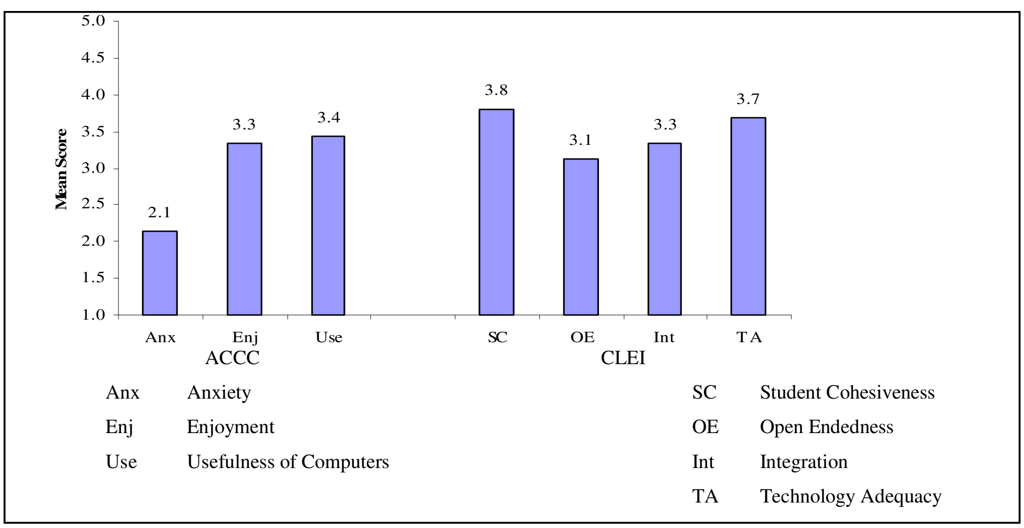


Figure 10.1. Mean ACCC and CLEI scores.

Within this learning environment students have a low level of anxiety with regards to using technology. This is coupled with a high level of enjoyment when using the technology, and an overall perception that the technology is useful for their school work. This is reinforced by the students' belief that they work well together, as indicated by the Student Cohesiveness results. They believe that the lessons are open-ended, implying that they have some control about what they will study. This open-ended approach integrates theoretical components with the technology; technology is not simply used as a perfunctory additive.

The QTI provides data about the teacher-student relationships as perceived by the students. The mean student responses for the QTI scales are shown in Table 10.7 and in Figure 10.2.

Table 10.7

Mean Scores for the QTI Scales

QTI Scale	Mean Score	QTI Scale	Mean Score
Leadership	2.6	Uncertain	0.7
Helping / Friendly	3.0	Dissatisfied	1.0
Understanding	2.8	Admonishing	1.0
Student Responsibility	1.8	Strict	1.5

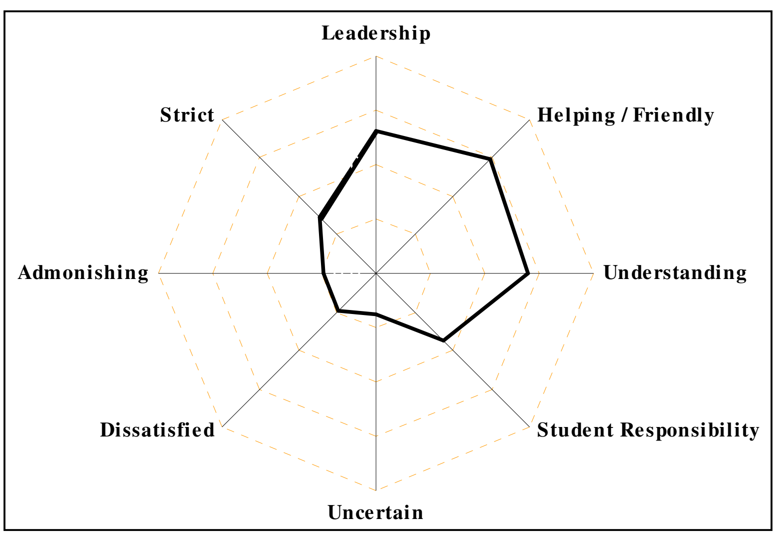


Figure 10.2. Mean scores for the QTI scales.

10.3.2 Discussion of Results

Figure 5.7 shows the QTI profiles for different teacher-student relationships. For ease of comparison these are redrawn in Figure 10.3 as radar plots.

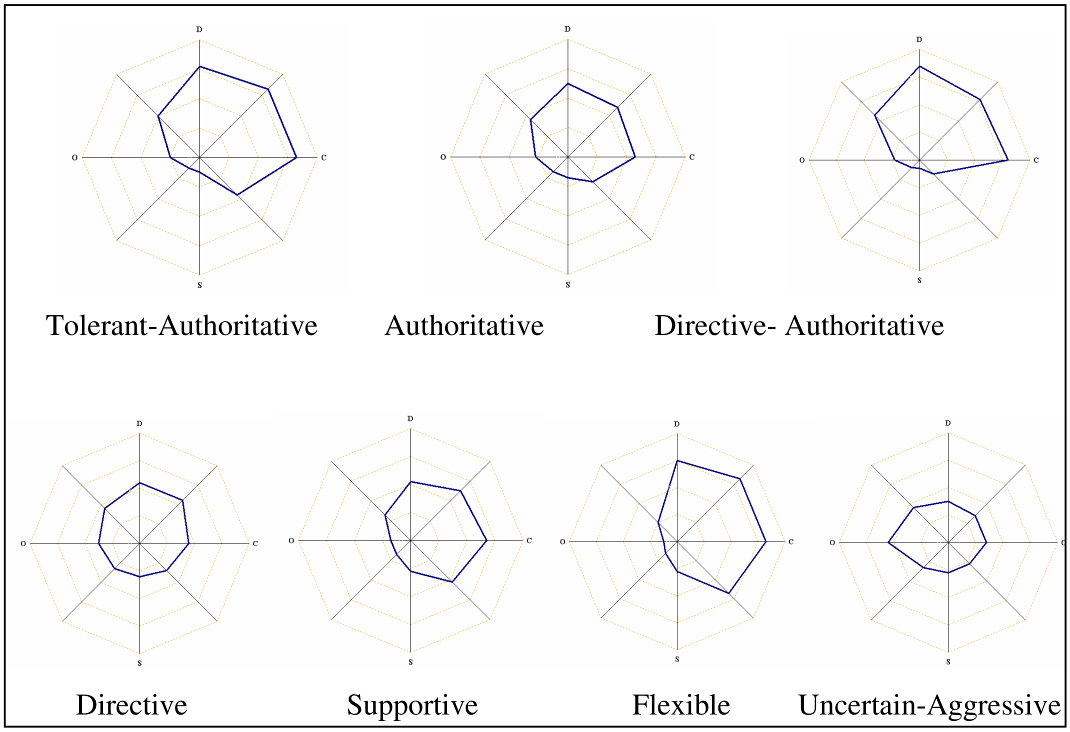


Figure 10.3. Australian classroom typologies shown as radar plots.

By comparing Figures 10.2 and 10.3 it is evident that the data obtained from the research cohort resembles the profile of a flexible teacher.

A social constructivist learning environment is usually portrayed by the flexible typology (Fisher, 2005, pers. com.). Figure 10.2 suggests that while this learning environment has a proclivity towards social constructivism, this has not yet been fully realised. The classes in which this survey was conducted strive to provide students with the computing skills necessary to allow them to effectively use computers as a learning tool in their other academic subjects. Consequently, computers are presented as both productivity tools and mindtools. The step-by-step instructions that must be understood for a particular productivity tool are more closely aligned with a behaviourist approach to teaching. In time, this allows students to effectively use computers in a constructivist manner. This edifying approach would, in the short term, detract from a purely constructivist learning environment. When considered in conjunction with the data shown in Figure 10.3, the learning environment can be, in generalised terms, described as constructivist.

10.4 COMPUTER SKILLS

10.4.1 Results

In 2005 and 2006, all of the students in Years Seven, Eight and Nine were entered into the competition, irrespective of their individual computing skills. The results are summarised in Table 10.8.

Table 10.8

Comparison of Mean ASCSC Scores 2005-06

Year		School	State	% of School Cohort in the State:		
				50%	30%	10%
2005	Mean Score ($^x/_{45}$)	24.1	22.7	58.9	40.8	11.2
	N	404	1326			
2006	Mean Score ($^x/_{45}$)	20.0	18.8	66.3	40.8	11.6
	N	380	1577			

Table 10.8 shows that, on average, the research cohort scores are 2% higher than the State mean scores. Furthermore, the research cohort has greater than 40% of its students in the top 30% of the State scores,

10.4.2 Discussion of Results

Chapter Eight describes the format of the ASCSC, which is designed to assess students' computer skills and knowledge outlined in the various State curricula. Prior to 2005 students entered this competition on a voluntary basis, resulting in low numbers relative to later years. Student performance for 2002-03 compared to the State are summarised in Table 10.9.

Table 10.9

Comparison of Mean ASCSC Scores 2002-03

Year		School	State
2002	Mean Score ($^x/_{45}$)	27.5	25.3
	N	19	1846
2003	Mean Score ($^x/_{45}$)	29.7	27.9
	N	56	1357

Whilst Table 10.9 indicates a higher mean result for the school than for the State, this may not be a true reflection of the students' level of computing skills. As the test was sat by volunteers, it could be argued that the volunteers had an 'above average' interest in technology, which could inflate the school's results. However, this could also apply to the students of other schools involved in the test.

The 2% difference between the mean results for the school and State has been maintained when the complete cohort is considered in Table 10.8. Furthermore, 40% of the school cohort results lie within the top 30% of the State results. Eleven percent of the school cohort lies within the top 10% of the State results. This can be further analysed using the Chi-squared test of the hypotheses:

H_0: There is no significant difference between the observed and expected mean values.

H_1: There is a significant difference between the observed and expected mean values.

Chi-squared values are shown in Table 10.10.

Table 10.10

Chi-Squared Value for the School Cohort

	% of School Cohort in the State:		
	50%	30%	10%
Observed	66.3	40.8	11.6
Expected	50.0	30.0	10.0
Chi2	9.491**		

** Significant at the 0.01 level

The calculated Chi-squared value in Table 10.10 indicates that the null hypothesis (H_0) should be rejected, in favour of the alternate hypothesis (H_1), that there is a significant difference between the observed and expected mean values. The inference is that these differences arise from within the technology-rich learning environment. The scope of technology integration in the 'State' cohort is unknown.

10.5 CRITICAL THINKING SKILLS

10.5.1 Results

Three groups of students were videorecorded as they completed the EWCTET, to identify the different levels of cognitive activity described by Anderson and Krathwoh, (2001) that they employed. Cognitive activity was determined from the questions asked of the teacher, discussions between students, and their behaviour during the task. Examples are shown in Table 10.11.

Table 10.11

Observations of Anderson and Krathwohl's Cognitive Dimension

Cognitive Dimension	Knowledge Dimension	Example of student dialogue and/or activity
Disengaged		[Discussion of TV shows]
Remembering	Factual	I'm not sure what we have to do We have to read the letter
	Conceptual	Do you choose one of them [Tasks]?
	Procedural	No, you have to do both.
	Metacognitive	-
Understanding	Factual	[Listening to instructions]
	Conceptual Procedural	Are we supposed to put down our own objections and things?
	Metacognitive	So, we're responding as though this letter was written to us.
Applying	Factual Conceptual Procedural Metacognitive	[Working on set task following prescribed format – identifying, clarifying and responding to a point of view]
Analysing	Factual	From [paragraph] five onwards it's all about accidents. He's using a lot of facts, but it's too much facts because it's kind of the same thing
	Conceptual	I don't get what it means by … [Reads aloud from task]
	Procedural	-
	Metacognitive	I disagree with this point here. [Points to screen]

Evaluating	Factual	It's not very clear. [The argument]
	Conceptual	Explains personal response to presented arguments to partner, relating to authentic conditions close to the school
	Procedural	-
	Metacognitive	The debate is not good – he needs to get proof The person needs to write the letter more clearly so that whom he is sending it to can understand it better.
Creating	Factual	-
	Conceptual Procedural	Make it that they have to pay for it, or get a parking ticket.
	Metacognitive	Maybe they could widen the streets by taking out the pathways. [Elaborates in detail, based on personal knowledge of a similar situation in rural Australia]

*Disengaged activities are those that occur when students engage in activities not related to the assignment

The time each group of students spent operating at the different cognitive levels is shown in Table 10.12.

Table 10.12

Occurrences of Anderson and Krathwohl's Dimensions

	% Lesson time at each level		
	Group		
Level	1	2	3
Disengaged	46.8	32.9	20.3
Remembering	13.3	19.9	11.8
Understanding	3.3	1.3	2.5
Applying	32.1	45.9	37.6
Analysing	4.6		18.6
Evaluating			4.7
Creating			4.5
	100	100	100

Students' performances for this task are shown in Table 10.13.

Table 10.13

Student Performance for the EWCTET

Marks	Critical Thinking Skill: Recognise False Analogy	Recognise Irrelevant Argument	Recognise Correct Argument	Recognise No Support	Recognise Alternative Arguments	Recognise Poor Experimental Design	Recognise Poor Definition	Recognise Emotive Language & Provide Coherent Summary	Total
Maximum Possible	3	3	6	3	3	3	3	5	29
Maximum Gained	3	3	6	3	3	3	3	5	#21
Average	0.45	0.58	2.33	0.71	0.79	0.86	0.75	0.54	##5.96

#This is the highest score attained by a student, not the sum of the maximum scores gained by the student cohort
##This is the mean total score, not the sum of the mean scores for each question

10.5.2 Discussion of Results

When addressing the issues raised in the EWCTET students did not automatically move to a level of higher cognition. Recorded observations between students indicate that they move to higher order thinking from a basis of lower order thinking during the early stages of the lesson. All observed groups spent time at the lower taxonomic levels of Anderson and Krathwohl (2001), and the interactions between the students allowed them to achieve higher order thinking skills.

Figures 10.4, 10.5 and 10.6 show the changing cognitive levels of the students as the EWCTET progressed. It was not always possible to clearly identify the dimension into which student dialogue or behaviour belonged. This resulted in some of the dimensions be merged and others apparently unaddressed, as shown in Tables 9.6 and 9.7.

Group One spent little time in studying the arguments to be addressed. Instead, they launched into their response at a low cognitive level. Figure 10.4 demonstrates that they spent most of their time engaged at the *applying* level, frequently reverting to off-task behaviour. This group was engaged at an analysis level, the lowest of the higher cognitive levels, for less than five per cent of the class time, and did not reach a higher level of engagement.

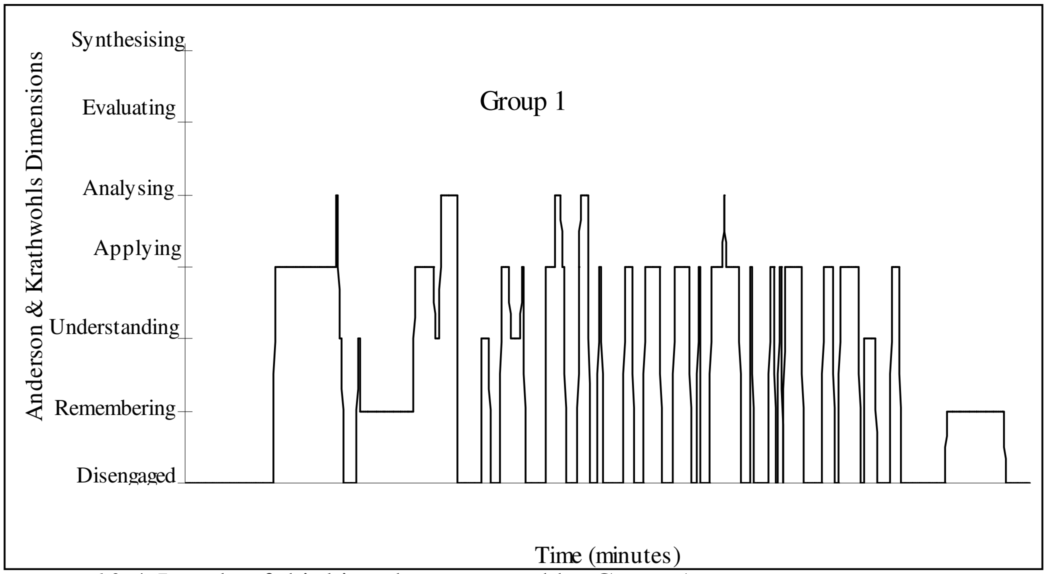


Figure 10.4. Levels of thinking demonstrated by Group 1.

The short bursts of time spent at the *applying* and *analysis* levels were quickly followed by off-task activities. This group would often ask members within the group questions such as “What does this mean?” or “What do we do here?” indicating a poor understanding of the task.

Group Two followed a similar pattern of off-task and low-cognitive activity, shown in Figure 10.5. The first 17 minutes of the lesson were spent discussing the requirements of the task at *remembering* and *understanding* levels, alternating with off-task behaviour. It is probable that this would have continued for a greater proportion of the lesson had not the teacher intervened and re-focussed their activities. However, this group continued to struggle with the task, and at no stage were they observed to be operating at a level higher than *applying*.

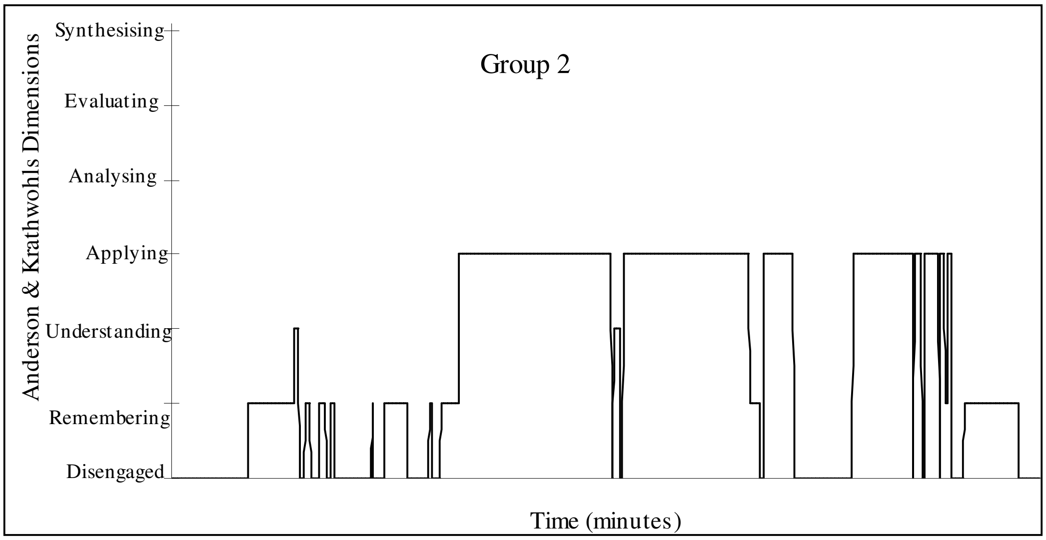


Figure 10.5. Levels of thinking demonstrated by Group 2.

Group Three, shown in Figure 10.6, displayed a learning pattern that suggests better personal organisation, better understanding of the task, and the ability to operate at higher cognitive levels. The early stages of the lesson were characterised by quiet reflection of the task, followed by group discussion in which the requirements were clarified. This was followed by discussions indicative of higher order thinking as described in Table 10.11. After higher level discussions the group appears to move to a lower cognitive level (*applying*) during which they are using their discussion to form their critical thinking responses.

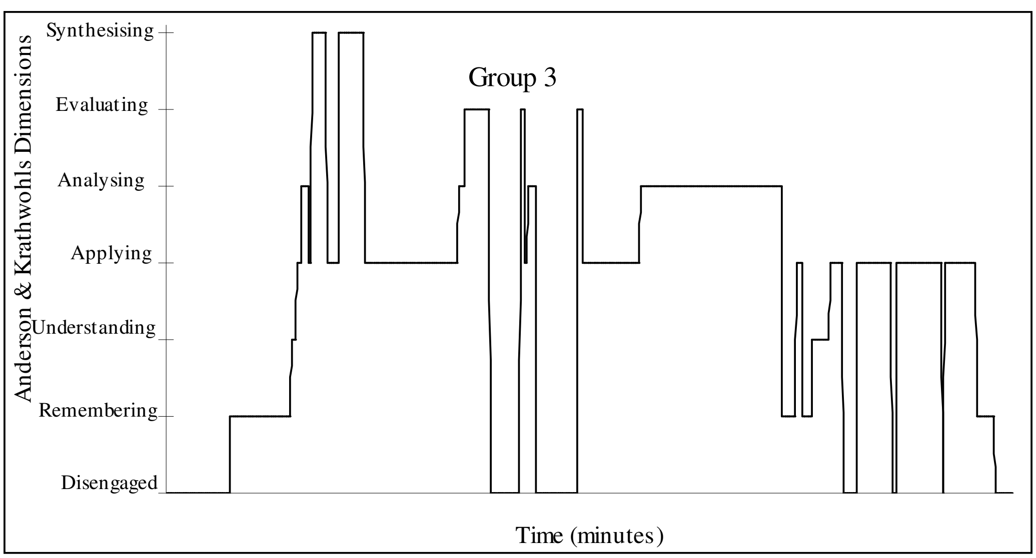


Figure 10.6. Levels of Thinking demonstrated by Group 3.

The observations of disengaged activity for this group were problematic. A discussion of a favourite TV show coincided with data entry into the computer. The conversation would then radically change direction with “OK, how does this sound…” followed by an oration of their argument. The higher order thinking had taken place; recording their thinking on the computer did not require a high level of concentration, as indicated by their off-task conversation. Yet, was this group actually off-task? To paraphrase da Vinci (n.d., in Gombrich & Rodgers, 1993), it is difficult to clearly identify cognitive activity as it has to be interpreted from the behaviour of the individual.

Data in Table 10.13 initially suggest that the general level of critical thinking skills is low. An average score of $^{6}/_{29}$ is considerably short of the generally accepted ‘pass mark’ of 50%, or $^{15}/_{29}$. It should be remembered that the EWCTET is designed for secondary and tertiary students (Ennis & Weir, 1985). It is reasonable to assume that tertiary students would, on average, perform better than secondary students. Therefore an acceptable pass mark for tertiary students would be higher than that for those still at a junior grade, secondary level.

Rather than considering the test in terms of *pass* or *fail*, it can be viewed as an open-ended instrument. Data from previous administrations of the EWCTET is shown in Table 10.14.

Table 10.14

Mean Scores for the EWCTET

Source	Age Group	Number of Students	Mean Score
Davidson & Dunham (1996)	1st Year, Junior College	19	6.6
		12	4.3
		14	1.8
		10	4.7
Hatcher (2004)	1st Year University	169	6.3
		119	9.4
		178	6.8
		178	8.1
		164	7.5
		169	6.9
Hatcher (1995)	Final Year University	66	9.6

If the data Table 10.14 are compared with the data from Table 10.13 (mean score = 5.96) it appears that the general standard of critical thinking skills transcends the critical thinking skills of college level students. When examining the thinking skills measured by the EWCTET, the highest mean scores relate to the students' ability to recognise a logical argument and arguments involving experimental design. Whilst critical thinking skills are not specifically taught within this learning environment, all students were in their third year of science classes that do address the scientific method, which includes the accurate design and execution of experiments.

Within the researched learning environment, science classes use technology extensively. Spiro's cognitive flexibility theory, described in Chapter Four (Spiro, 1991), explains how students can restructure their thinking as a means of adapting to new situations (Swindler, 2001). Swain, Greer and van Hover (2001) argue that the flexibility provided by computers make them an ideal learning tool employing the cognitive flexibility theory. It seems evident that students are transferring their critical thinking skills, developed within a technology-based science education environment, to other learning situations.

10.6 CREATIVE THINKING SKILLS

10.6.1 Results

The SCSM measures students' creative thinking across three domains: Fluency, Flexibility and Originality. These domains are measured within different scientific contexts, providing a broader précis of student creativity. Mean student scores (for the test group) for these domains are shown in Table 10.15. As the SCSM is open-ended there is no maximum score possible for any question. The mean scores are presented within the range of scores for each question.

Table 10.15

Mean Student Scores for the SCSM

Question	Scientific Context	Parameter	Fluency	Flexibility	Originality
1	Science Knowledge	Max	29	15	16
		Min	3	1	0
		Mean	12	6	3
2	Sensitivity to Scientific Problems	Max	38	22	28
		Min	2	2	0
		Mean	16	9	11
3	Technical Production	Max	45	23	51
		Min	1	1	0
		Mean	12	8	11
4	Scientific Imagination	Max	24	14	25
		Min	0	0	0
		Mean	8	6	9
5	Problem Solving	Max	-	71	107
		Min	-	6	5
		Mean	-	28	33
6	Experimental Design	Max	-	25	14
		Min	-	0	0
		Mean	-	5	2
7	Technical Production	Max	-	27	5
		Min	-	0	0
		Mean	-	13	2

N = 150

10.6.2 Discussion of Results

Assessing creativity is a complex process. There can be no test with ‘right’ or ‘wrong’ answers when it is recalled that creativity involves the synthesis of original solutions. Creative thinking involves the critical analysis of existing information, coupled with innovation and a ‘novelty’ factor (Pears, 1996). To be considered as correct or incorrect, answers would have been preconceived, and therefore are not original. Tests such as the TTCT and the SCSM derive their answers from the degree of originality expressed by the cohort sitting the test. If many students produce the same, or similar, solutions, then those solutions have a lesser quality of originality than a solution proposed by only one student. Such an approach leads to some interesting insights into adolescent creative thinking tempered with colloquial Australian language. When responding to the question “Suppose there was no gravity – describe what the world would be like” one student responded with:

> *“Life would sort of suck.”*

It follows that, while open-ended critical thinking tests such as the EWCTET can have a maximum score, the open-ended creative thinking SCSM test cannot. As stated in Chapter One, the SCSM is a relatively new instrument. Existing results from previous administrations of the test are therefore limited. A comparison of the mean scores for three age groups (Hu & Adey, 2002) and the mean score for the research cohort are shown in Table 10.16.

Table 10.16

Mean Scores for the SCSM

Age	N	Mean	Standard Deviation
12	58	45	20.18
13	49	57	21.25
*14	150*	110*	44.79*
15	53	63	23.45

*Current Research Cohort

Data in Table 10.16 suggest that the current research cohort has a considerably higher level of creative thinking ability when compared to the original groups. However, it must be emphasised that the data are limited. Only the mean scores of the original data are reported. Breaking this down into the scales of Fluency, Flexibility and Originality would provide illumination. The creators of this test acknowledge that further research is required.

10.7 SUMMARY

The key questions that this research answers, "What is the relationship between technology-rich learning environments and the development of higher order thinking skills?" and "To what extent are higher order thinking skills demonstrated by students in a technology-rich environment?" require that the quality of the technology-rich environment is made explicit.

The data presented and discussed in this chapter portray a mature learning environment. The use of technology has evolved from precarious beginnings to a point at which it is eagerly embraced by the majority of staff and students, and by its integration across the curricula. The technological skills of the students can be paralleled with the productivity tools described by Jonassen (1996) in Chapter Four, applied in different learning areas as mindtools. Data in Table 10.14 indicate a level of critical thinking on par with that found at university.

This suppurate environment uses technology most efficiently; students' technology skills are developed by the teachers in specialist classes and used to develop their cognition elsewhere, by teachers who may not share those same skills. The learning environment can indeed be described as technology-rich.

Data in Tables 10.13 and 10.14 indicate that above average computer skills exist within this learning environment when compared to those of the State. Similarly, data in Tables 10.13, 10.14 and 10.15 indicate above average critical and creative thinking skills within this learning environment. The next chapter presents and statistically analyses data pertaining to the hypotheses listed in Chapter Eight. Correlations between the factors within the technology-rich learning environment are shown.

CHAPTER 11

STATISTICAL TESTING OF THE HYPOTHESES

11.1 INTRODUCTION

Chapter Eight presents the research questions as hypotheses that can be statistically measured. In this chapter the hypotheses are presented in conjunction with the relevant correlation coefficients. On the basis of the correlations, measured at the 0.01 and 0.05 levels of significance, the hypotheses are either accepted or rejected. The hypotheses are further examined by examining correlations that exist between the scales contained within the different research instruments.

11.2 STUDENT PERCEPTIONS OF TECHNOLOGY-RICH LEARNING ENVIRONMENTS

11.2.1 Results

1.1. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and their attitude towards computers.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and their attitude towards computers.

Table 11.1

Spearman's Correlations for the CLEI and ACCC Scales

CLEI scale		ACCC scale Anxiety	Enjoyment	Usefulness
Student Cohesiveness	Rho	-0.213**	0.285**	0.228**
Open Endedness	Rho	-0.224**	0.426**	0.284**
Integration	Rho	-0.269**	0.440**	0.366**
Technology Adequacy	Rho	-0.395**	0.439**	0.294**

**Correlation is significant at the 0.01 level (1-tailed). N = 121

Reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that there are significant correlations between all of the CLEI and ACCC scales.

1.2. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and their level of technological skill.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and their level of technological skill.

Table 11.2

Spearman's Correlations for the CLEI Scales and ASCSC Scores

		CLEI scale			
		Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
ASCSC	Rho	0.057	0.062	0.253*	0.181*

*Correlation is significant at the 0.05 level (1-tailed). N = 105

Accept the null hypothesis (H_0) that there is no significant correlation between the ASCSC score and the Student Cohesiveness and Open Endedness scales. Reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that there is a significant correlation between the ASCSC score and the Integration and Technology Adequacy scales.

1.3. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and the student-teacher relationship within that learning environment.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and the student-teacher relationship within that learning environment.

Table 11.3

Spearman's Correlations for the CLEI and QTI Scales

QTI scale		CLEI scale: Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
Leadership	Rho	0.201*	0.074	0.230**	0.296**
	N	111	111	111	111
Helping / Friendly	Rho	0.256**	0.142	0.304**	0.232**
	N	110	110	110	110
Understanding	Rho	0.190*	0.221**	0.276**	0.261**
	N	111	111	111	111
Student Responsibility	Rho	-0.016	-0.195*	-0.239**	-0.263*
	N	110	110	110	110
Uncertainty	Rho	-0.185*	0.003	-0.331**	-0.198*
	N	111	111	111	111
Dissatisfaction	Rho	-0.289**	-0.187*	-0.306**	-0.399**
	N	110	110	110	110
Amonishing	Rho	-0.033	-0.094	-0.310**	-0.267**
	N	111	111	111	111
Strict	Rho	0.010	0.179*	0.197*	0.115
	N	110	110	110	110

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)

Reject the null hypothesis (H_0) and accept the alternate hypothesis that there is a significant correlation between student perceptions of technology-rich learning environments and the student-teacher relationship within that learning environment.

1.4. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and the development of critical thinking skills.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and the development of critical thinking skills.

Table 11.4

Spearman's Correlations for the CLEI Scales and the EWCTET Scores

		CLEI Scale			
		Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
EWCTET	Rho	0.032	0.222*	0.240**	0.115

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)
N = 106

Accept the null hypothesis (H_0) that there is no significant correlation between between student perceptions of technology-rich learning environments and the development of critical thinking skills for the CLEI scales of Student Cohesiveness and Technology Adequacy. Reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that there is a significant correlation between student perceptions of technology-rich learning environments and the development of critical thinking skills for the CLEI scales of Open Endedness and Integration.

1.5. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and the development of creative thinking skills.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and the development of creative thinking skills.

Table 11.5

Spearman's Correlations for the CLEI Scales and SCSM Scores

		CLEI scale			
		Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
SCSM	Rho	-0.095	-0.055	0.135	0.092

N = 116

Accept the null hypothesis (H_0) that there is no significant correlation between student perceptions of technology-rich learning environments and the development of creative thinking skills.

1.6. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and their length of time within the environment.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and their length of time within the environment.

Table 11.6

Spearman's Correlations for the CLEI Scales and the Length of Enrolment

		CLEI scale			
		Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
Length of Enrolment	Rho	0.021	-0.022	-0.104	0.026

N = 119

Accept the null hypothesis (H_0) that there is no significant correlation between student perceptions of technology-rich learning environments and their length of time within the environment.

1.7. H_0: There is no significant correlation between student perceptions of technology-rich learning environments and the age of the technology.

H_1: There is a significant correlation between student perceptions of technology-rich learning environments and the age of the technology.

Table 11.7

Spearman's Correlations for the CLEI Scales and the Age of the Technology

		CLEI Scale			
		Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
Age of the Technology	Rho	0.074	-0.043	0.015	-0.088

N = 117

Accept the null hypothesis (H_0) that there is no significant correlation between student perceptions of technology-rich learning environments and the age of the technology.

11.2.2 Discussion of Results

Table 11.1 shows that the ACCC scales of Enjoyment and Computer Usefulness have strong, positive correlations with all four of the CLEI scales: Student Cohesiveness, Open-Endedness, Integration and Technology Adequacy. Conversely, there is a strong negative correlation between the ACCC Anxiety scale and all of the CLEI scales. This raises the argument – why use both instruments? When the significant correlations between these two instruments and the QTI, shown in Tables 11.3 and 11.13 (Page 202), are also considered, this question must be extended.

Correlations between these instruments and the other factors studied within this research environment show that not all of the CLEI, ACCC and QTI scales correlate significantly with all other factors, for example critical thinking scores or computer skills. To determine the extent to which the human perceptions measured by the CLEI, ACCC and QTI relate to these other factors they must be examined separately.

Table 11.2 shows that there are significant correlations between students' computer skills, as measured by the ASCSC, and students who perceive the technology to be integrated with specific subjects, and adequate for their needs. There is no significant correlation between students' computer skills and the extent to which they perceive the environment to be one in which there is a high degree of student cohesion. Correlations between the CLEI scales and ASCSC scales are shown in Table 11.8.

Table 11.8

Spearman's Correlations for the CLEI and ASCSC Scales

		CLEI Scale			
ASCSC Scale		Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
Productivity Tools	Rho	0.036	-0.090	0.134	-0.027
Software	Rho	-0.062	0.049	0.198*	0.077
Communications	Rho	0.125	0.059	0.073	0.215*
Internet	Rho	0.024	0.137	0.194*	0.241**
Hardware	Rho	0.013	0.017	0.023	0.031
Programming	Rho	0.143	0.059	0.208*	0.168*

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)
N = 105

The correlations are significant for those computer skills that require a higher level of cognition. For example, computer programming. While student cohesiveness and open-ended tasks are significant components of socially constructivist classes, they do not have a significant correlation with higher order computing skills.

Table 11.4 demonstrates that this relationship is different when considering CLEI scales and critical thinking scales. In this instance, the degree of student cohesion does have a significant correlation with critical thinking. Within a socially constructivist setting students are encouraged to work together when solving problems. The ensuing dialogue helps to develop a better understanding of the topic and allows students to attain higher levels of cognition, as demonstrated by Figure 10.6.

There does not appear to be a significant correlation between the CLEI scales and creative thinking, as shown in Table 11.5. If The SCSM is broken into its constituent scales, shown in Table 11.9, there is a significant correlation between CLEI Integration and SCSM Originality.

Table 11.9

Spearman's Correlations for the CLEI and SCSM Scales

		CLEI scale			
SCSM scale		Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
Fluency	Rho	-0.128	-0.090	0.080	0.038
Flexibility	Rho	0.006	-0.114	0.081	0.021
Originality	Rho	-0.011	-0.109	0.199*	0.096

*Correlation is significant at the 0.05 level (1-tailed) N = 116

This correlation appears to relate to creative thinking within the context of problem sensitivity (SCSM Question Two) as shown in Table 11.10.

Table 11.10

Spearman's Correlations for the CLEI and SCSM Questions

SCSM Question		CLEI scale Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
Q1	Rho	-0.024	-0.012	0.085	0.068
Q2	Rho	-0.078	-0.098	0.166*	0.072
Q3	Rho	-0.058	-0.035	0.121	0.081
Q4	Rho	-0.108	0.014	0.031	0.143

*Correlation is significant at the 0.05 level (1-tailed) N= 116

Question Two can be broken into the three SCSM scales that it measures, as shown in Table 11.11.

Table 11.11

Spearman's Correlations for the CLEI and SCSM Question Two Scales

SCSM scale		CLEI scale Student Cohesiveness	Open Endedness	Integration	Technology Adequacy
Fluency	Rho	-0.129	-0.097	0.076	0.008
	N	116	116	116	116
Flexibility	Rho	-0.021	-0.022	0.100	0.084
	N	116	116	116	116
Originality	Rho	-0.004	-0.061	0.157*	0.180*
	N	121	121	121	121

*Correlation is significant at the 0.05 level (1-tailed)

The significant correlation exists between the CLEI scales of Integration and Technology Adequacy, and the SCSM scale of Originality within the context of sensitivity to scientific problems.

11.3 STUDENT ATTITUDES TOWARDS COMPUTERS

11.3.1 Results

2.1. H_0: There is no significant correlation between student attitudes towards computers and their level of technological skill.

H_1: There is a significant correlation between student attitudes towards computers and their level of technological skill.

Table 11.12

Spearman's Correlation for the ACCC Scales and ASCSC Scores

		ACCC Scale		
		Anxiety	Enjoyment	Usefulness of Computers
ASCSC	Rho	-0.287*	0.281**	0.110

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)
N = 105

Accept the null hypothesis (H_0) that there is no significant correlation between the ASCSC score and the ACCC scale Usefulness of Computers. Reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that there is a significant correlation between the ASCSC score and the ACCC scales of Anxiety and Enjoyment.

2.2. H_0: There is no significant correlation between student attitudes towards computers and the student-teacher relationship within the learning environment.

H_1: There is a significant correlation between student attitudes towards computers and the student-teacher relationship within the learning environment.

Table 11.13

Spearman's Correlations for the ACCC Scales and the QTI Scales

QTI scale		Anxiety	ACCC scale Enjoyment	Usefulness
Leadership	Rho	-0.367**	0.242**	0.294**
	N	111	111	111
Helping / Friendly	Rho	-0.224**	0.155	0.216*
	N	110	110	110
Understanding	Rho	-0.331**	0.245**	0.289**
	N	111	111	111
Student Responsibility	Rho	0.243**	-0.245*	-0.002
	N	110	110	110
Uncertainty	Rho	0.179*	-0.121	-0.192*
	N	111	111	111
Dissatisfaction	Rho	0.444**	-0.218*	-0.184*
	N	110	110	110
Amonishing	Rho	0.174*	-0.177*	-0.151
	N	111	111	111
Strict	Rho	0.054	0.261*	-0.017
	N	110	110	110

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)

Reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that there are signifcant correlations between the QTI scales and the ACCC scales.

2.3. H_0: There is no significant correlation between student attitudes towards computers and the development of critical thinking skills.

H_1: There is a significant correlation between student attitudes towards computers and the development of critical thinking skills.

Table 11.14

Spearman's Correlations for the ACCC Scales and EWCTET Scores

		ACCC Scale		
		Anxiety	Enjoyment	Usefulness
EWCTET	Rho	-0.016	0.075	0.115

N = 106

Accept the null hypothesis (H_0) that there is no significant correlation between the ACCC scales and the development of critical thinking skills.

2.4. H_0: There is no significant correlation between student attitudes towards computers and the development of creative thinking skills.

H_1: There is a significant correlation between student attitudes towards computers and the development of creative thinking skills.

Table 11.15

Spearman's Correlations for the ACCC Scales and SCSM Scores

		ACCC Scale		
		Anxiety	Enjoyment	Usefulness
SCSM	Rho	-0.027	0.009	0.135

N = 116

Accept the null hypothesis (H_0) that there is no significant correlation between the ACCC scales and the development of creative thinking skills.

2.5. H_0: There is no significant correlation between student attitudes towards computers and length of time within the environment.

H_1: There is a significant correlation between student attitudes towards computers and length of time within the environment.

Table 11.16

Spearman's Correlations for the ACCC Scales and Length of Enrolment

		ACCC scale		
		Anxiety	Enjoyment	Usefulness
Length of Enrolment	Rho	0.127	0.107	0.178*

*Correlation is significant at the 0.05 level (1-tailed). N = 119

Accept the null hypothesis (H_0) that there is no significant correlation between the ACCC scales of Anxiety and Enjoyment, and the length of time within the environment. Reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that there is a significant correlation between the ACCC scale of Usefulness and the length of time in the environment.

2.6. H_0: There is no significant correlation between student attitudes towards computers and the age of the technology.

H_1: There is a significant correlation between student attitudes towards computers and the age of the technology.

Table 11.17

Spearman's Correlations for the ACCC Scales and Age of the Technology

		ACCC scale		
		Anxiety	Enjoyment	Usefulness
Age of Technology	Rho	0.122	-0.105	-0.121

N = 117

Accept the null hypothesis (H_0) that there is no significant correlation between the ACCC scales and the age of the technology.

11.3.2 Discussion of Results

Data in Table 11.12 demonstrate that there is a significant, positive correlation between students who enjoy using computers and demonstrate a higher level of computer skills. This is supported by a significant negative correlation between levels of anxiety and levels of computer skills. This can be examined by returning to the works of Beyer (1985) and Huitt (1999), described in Chapters Two and Three. Beyer and Huitt acknowledge the importance of conation in developing higher levels of cognition. Students who are enjoying using the technology have greater motivation to ask the "why" questions necessary to achieve higher skills with the technology.

There is no significant correlation between the ACCC scales and the development of critical and creative thinking, as measured by the EWCTET and SCSM. This appears to contradict the previous paragraph. It may be that the enjoyment of pursuing knowledge at higher levels is not sufficient to gain that knowledge. The EWCTET is not designed to break critical thinking into subsets that can be measured in the same way as the SCSM. Correlations between the ACCC and SCSM scales are shown in Table 11.18.

Table 11.18

Spearman's Correlations for the ACCC Scales and SCSM Scales

		SCSM Scale		
ACCC Scale		Fluency	Flexibility	Originality
Anxiety	Rho	0.002	0.021	0.096
Enjoyment	Rho	-0.036	-0.051	-0.116
Usefulness of Computers	Rho	0.077	0.148	0.161*

*Correlation is significant at the 0.05 level (1-tailed). N = 116

Data in Table 11.18 demonstrates that there is a significant relationship between students who perceive computers to be useful and those who demonstrate higher levels of original thinking. Correlations between the ACCC scales and SCSM questions that measure the SCSM scales within specific contexts are shown in Table 11.19.

Table 11.19

Spearman's Correlations for the ACCC Scales and SCSM Questions

ACCC Scale		SCSM Question Q1	Q2	Q3	Q4
Anxiety	Rho	-0.004	-0.130	0.026	0.039
Enjoyment	Rho	0.051	-0.058	0.013	0.036
Usefulness of Computers	Rho	0.128	0.232**	0.100	0.061

**Correlation is significant at the 0.01 level (1-tailed). N = 116

The correlation between the ACCC scale Usefulness of Computers is most significant when considered in the context of SCSM Question Two, which addresses sensitivity to scientific issues. Question Two can be further devolved into its component scales, shown in Table 11.20.

Table 11.20

Spearman's Correlations for the ACCC Scales and SCSM Question Two Scales

ACCC Scale		SCSM Question Two Scale Fluency	Flexibility	Originality
Anxiety	Rho	-0.012	-0.168*	-0.246**
	N	116	116	121
Enjoyment	Rho	-0.093	-0.020	0.035
	N	116	116	121
Usefulness of Computers	Rho	0.141	0.248**	0.219**
	N	116	116	121

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)

Data in Table 11.20 shows a significant correlation between the ACCC scale Usefulness of Computers and the SCSM scales of Flexibility and Originality, within the context of senstitivity towards scientific issues. This is reinforced by a significant, negative correlation between the SCSM scales and the ACCC Anxiety scale. It appears that students who have lower level of anxiety about technology, and enjoy using their computers, are better conatively positioned to develop higher levels of creative thinking.

11.4 STUDENTS' COMPUTER SKILLS:

11.4.1 Results

3.1. H_0: There is no significant correlation between students' computer skills and student-teacher relationship within the learning environment.

H_1: There is a significant correlation between students' computer skills and student-teacher relationship within the learning environment.

Table 11.21

Spearman's Correlations for the QTI Scales and ASCSC Score

QTI Scale		ASCSC Score
Leadership	Rho	0.193*
	N	122
Helping / Friendly	Rho	0.108
	N	121
Understanding	Rho	0.187*
	N	122
Student Responsibility	Rho	-0.241*
	N	121
Uncertainty	Rho	-0.186*
	N	122
Dissatisfaction	Rho	-0.284**
	N	121
Admonishing	Rho	-0.166*
	N	122
Strict	Rho	0.033
	N	121

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)

For the QTI scales of Helping/Friendly and Strict accept the null hypothesis (H_0) that there is no significant correlation between teacher-student relationships and the development of computer skills. For the QTI scales of Leadership, Understanding, Student Responsibility, Uncertainty, Dissatisfaction, and Admonishing, reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that there is a significant correlation between teacher-student relationships and the development of computer skills.

3.2 H_0: There is no significant correlation between students' computer skills and the development of critical thinking skills.

H_1: There is a significant correlation between students' computer skills and the development of critical thinking skills.

Spearman's correlation for the ASCSC and EWCTET total scores is 0.307 (N=116). This is significant at the 0.01 level, so the null hypothesis (H_0) should be rejected. Accept the alternate hypothesis ($H_{1,}$) that there is a significant correlation between students' computer skills and students' critical thinking skills.

3.3 H_0: There is no significant correlation between students' computer skills and the development of creative thinking skills.

H_1: There is a significant correlation between students' computer skills and the development of creative thinking skills.

Spearman's correlation for the ASCSC and SCSM total scores is 0.105 (N=128). This figure is not significant at the 0.05 level, so the null hypothesis (H_0) should be accepted. There is a no significant correlation between students' computer skills and students' creative thinking skills.

3.4 H_0: There is no significant correlation between students' computer skills and the length of time within the environment.

H_1: There is a significant correlation between students' computer skills and the length of time within the environment.

Spearman's correlation for the length of enrolment and ASCSC score is 0.154 (N=135). This is significant at the 0.05 level, so the null hypothesis (H_0) should be rejected. Accept the alternate hypothesis (H_1) that there is a significant correlation between students' computer skills and their length of time within the environment.

3.5 H_0: There is no significant correlation between students' computer skills and the age of the technology.

H_1: There is a significant correlation between students' computer skills and the age of the technology.

Spearman's correlation for the age of the students' computers and ASCSC scores is -0.039 (N=133). This is not significant at the 0.05 level, so the null hypothesis (H_0) should be accepted. There is no significant correlation between the age of the students' computers and the development of students' computing skills.

11.4.2 Discussion of Results

Table 11.21 shows significant correlations for some of the QTI scales with respect to the ASCSC scores. In some cases these significant correlations are positive; in others, negative. This is to be expected given the circumplex nature of the QTI. It would be unusual, if not erroneous, to obtain a significant positive correlation for the scales that are diametric; for example, Leadership and Uncertainty.

In addition to correlating the QTI scales with the overall ASCSC scores, correlations between all of the scales for both instruments are shown in Table 11.22.

Table 11.22

Spearman's Correlations for the QTI and ASCSC Scales

QTI Scale		ASCSC Scale: Productivity Tools	Internet	Communication	Hardware	Software	Programming
Leadership	Rho	0.088	0.089	0.127	0.055	0.193*	0.119
	N	122	123	122	123	122	123
Helping / Friendly	Rho	0.004	0.005	0.118	-0.029	0.206*	-0.057
	N	121	122	121	122	121	122
Understanding	Rho	0.011	0.129	0.114	0.081	0.135	0.203*
	N	122	123	122	123	122	123
Student Responsibility	Rho	-0.134	-0.124	-0.113	-0.153*	-0.117	-0.124
	N	121	122	121	122	121	122
Uncertainty	Rho	-0.058	-0.092	0.065	-0.163*	-0.109	-0.071
	N	122	123	122	123	122	123
Dissatisfaction	Rho	-0.181*	-0.150*	-0.153*	0.077	-0.174*	-0.301**
	N	121	122	121	122	121	122
Admonishing	Rho	0.012	-0.105	0.087	-0.199*	-0.056	-0.150*
	N	122	123	122	123	122	123
Strict	Rho	0.050	0.006	0.005	-0.009	0.070	0.035
	N	121	122	121	122	121	122

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)

The positive correlations are for those scales that could be considered as positive human traits; Leadership and Understanding. The data in Table 11.22 suggest that, while the learning environment approximates a constructivist atmosphere, the students that perceive it to be socially constructivist are those who display greater computing skills. This is supported by negative correlation for the 'negative' human attributes of Dissatisfaction and Admonishment. The strongest correlations relate to the higher order skill of computer programming. This trend continues with regards to computer programming skills and the development of higher order thinking skills.

Data in Section 11.4.1 shows a significant correlation between the students' computer skills, as measured by the ASCSC, and their critical thinking skills, as measured by the EWCTET. While it is tempting to conclude that the better use of a computer helps develop critical thinking, it must be remembered that the data show a correlation and not a causal relationship.

The EWCTET examines different aspects of critical thinking. As described in Section 9.4.2, this test cannot be reliably broken into these aspects but it can be treated as a reliable measure of critical thinking in total. The ASCSC is designed with questions that specifically address different scales of computer skills, and these scales have been shown to be reliable in Chapter Nine. Correlations between the score for these computer skill scales and scores for critical thinking are shown in Table 11.23.

Table 11.23

Spearman's Correlations for Critical Thinking and the Scales of Computer Skills

		ASCSC					
		Productivity Tools	Internet	Communication	Hardware	Software	Programming
EWCTET	Rho	0.108	0.229**	0.231**	0.034	0.196*	0.212*
	N	116	117	116	117	116	117

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)

The data show that the correlations are not significant for all of the scales used to measure students' computer skills. The greatest significance occurs for those scales that address higher order thinking skills, for example, the Internet and Programming scales. These scales require students to be able to apply Boolean logic, and analyse and evaluate programming script, as illustrated in Figures 11.1 and 11.2.

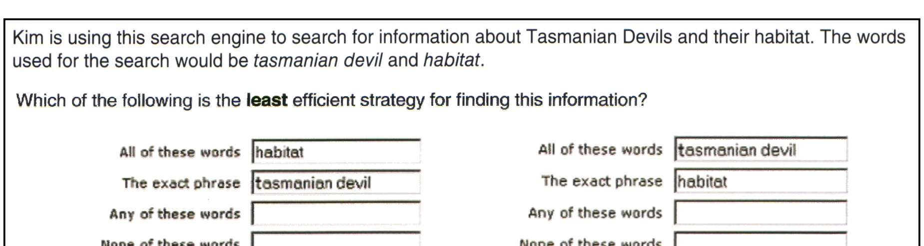
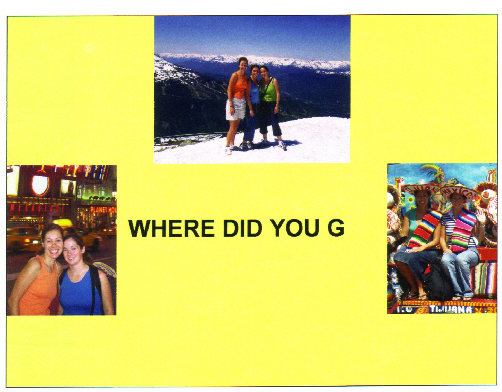


Figure 11.1. Higher order question requiring analysis and Boolean logic.

```
ScreenSaver by Kerry

Define images and text
Image/Text [screen1.bmp]
Image/Text [screen2.bmp]
Image/Text [screen3.bmp]
Image/Text [WHERE DID YOU GO?, TextColour: RGB(0, 0, 0), Font: Arial, ...]

Clear screen
Cls [Colour: RGB(255,255,255)]
Wait [Duration: 2 sec]

Start screen saver
Repeat (Repeat screen saver)

    Cls [Colour: Random]

    Display images
    Show Image [screen1.bmp, Position: (Left, Center), Effect: None [100], ]
    Show Image [screen2.bmp, Position: (Center, Top), Effect: None [100], ]
    Show Image [screen3.bmp, Position: (Right, Center), Effect: None [100], ]

    Display text
    Show Text [WHERE DID YOU GO?, Position: (Center, Center), Letter By Letter Speed: 1500]

    Move images
    Move Image [screen1.bmp, Start Position: (Left, Center), End Position: (Left, Bottom), Speed: 100000]
    Move Image [screen3.bmp, Start Position: (Right, Center), End Position: (Right, Bottom), Speed: 100000]

    Hide images
    Hide Image [screen2.bmp]

Until [Infinite]
End of script
```

Kerry previewed the screen saver and took a screen shot.



Which line of script is being carried out in the screen shot?

Figure 11.2. Higher order question requiring analysis and evaluation.

Papert (1972) imagined an educational environment in which students used computers as an extension of their mind. An advocate of teaching children how to program computers with Logo, Papert believed that the logical nature of programming coupled with the imaginations of children allows them to understand abstract principles by addressing them within a concrete framework. The data in Table 11.23 support this belief; students with better developed programming skills, developed within a technology-rich environment, score higher on critical and creative thinking exercises. While this is not to state that the better programming skills cause higher order thinking, it should be noted that the computer skills are explicitly taught within this educational environment. Higher order thinking skills are not.

Unlike the EWCTET the SCSM can be devolved into recognised scales of creative thinking. Correlations for the scales of the ASCSC and the SCSM are shown in Table 11.24.

Table 11.24

Spearman's Correlations for the ASCSC and the SCSM

ASCSC		SCSM Scales		
		Fluency	Flexibility	Originality
Productivity Tools	Rho	0.172*	0.168*	40.106
	N	128	128	128
Internet	Rho	0.137	0.040	40.180*
	N	129	129	129
Communications	Rho	-0.026	0.030	40.016
	N	128	128	128
Hardware	Rho	0.052	0.164*	40.158*
	N	129	129	129
Software	Rho	0.020	-0.084	40.040
	N	128	128	128
Programming	Rho	0.075	-0.006	40.162*
	N	129	129	129

*Correlation is significant at the 0.05 level (1-tailed)

Table 11.24 shows significant positive correlations for the lower order computer skills with Fluency and Flexibility. Concurrently there are positive correlations for the higher order computing skills with Originality. It could be argued that the three scales measured by the SCSM, Fluency, Flexibility and Originality, form their own hierarchy. Fluency only requires a number of ideas to be generated; Flexibility measures how these ideas differ from each other; and Originality requires the ideas to be different from those of other people. It then appears that high scores for lower order computer skills correlate significantly with high scores for the lower order creative thinking skills. The same pattern emerges for the higher order skills of both groups.

The SCSM also measures creative scales embedded in aspects of scientific activity, as described in Chapter Six. Correlations for the ASCSC scales and the scores for the SCSM Question One through to Question Four are shown in Table 11.25.

Table 11.25

Spearman's Correlations for the ASCSC Scales and SCSM Question Scores

ASCSC		SCSM Questions: 1 Scientific Knowledge	2 Problem Sensitivity	3 Product Development	4 Scientific Imagination
Productivity Tools	Rho	0.130	0.029	0.147*	0.083
	N	128	128	128	128
Internet	Rho	0.126	0.170*	0.114	0.065
	N	128	129	129	128
Communications	Rho	-0.009	-0.017	-0.028	0.026
	N	128	128	128	128
Hardware	Rho	0.060	-0.068	0.137	0.027
	N	129	129	129	129
Software	Rho	0.006	-0.035	0.011	0.048
	N	128	128	128	128
Programming	Rho	0.171*	0.104	0.053	0.043
	N	128	129	128	129

*Correlation is significant at the 0.05 level (1-tailed)

Significant correlations are again evident for lower and higher order computing skills with aspects of creative thinking. Several inferences can be drawn. Students' skills with productivity tools may allow them to apply these skills when manipulating scientific knowledge. The same skills allow students to manipulate technology when developing scientific solutions. Sensitivity to scientific knowledge is correlated with higher Internet skills; for example, Boolean searching. The ability to approach a problem from different aspects is seen as a necessary skill to perform successful Internet searching. The capacity to apply scientific knowledge in creative ways allows students to demonstrate a conceptual understanding of computer programming, the strongest correlation shown in Table 11.25. A parallel exists between these inferences and the use of computers as mindtools described by Jonassen (1996) in Chapter Four. Well developed computer skills allow students to manipulate technology to achieve higher levels of thinking.

Section 11.4.1 shows a significant correlation between the length of time students spend in the technology-rich environment and the development of their computer skills. It could be expected that, given this correlation, there would also be a significant correlation between the students' computer skills and the age of the computers.

Paradoxically, it could be argued that older computers are less reliable or efficient than more recent models, which could have a negative effect on the students' learning and development of computer skills. The data in Section 11.4.1 indicate that these outcomes are not met. There is no significant correlation, positive or negative, between students' computer skills and the age of the technology.

An important component of this technology-rich learning environment is the comprehensive technology support offered, in terms of hardware maintenance and software updates. Table 11.26 shows the total number of repairs carried out on the different models of notebook (indicated by their age), and the average turn-around time for the repairs (North, 2005).

Table 11.26

Notebook Repairs and Turn-around Time

Age of Notebook (Years)	Average Turnaround (Days)	Repairs (%)
1	0.6	11
2	2.4	4
3	0.5	34
4	0.4	48
5	2.2	2
Unknown	2.2	1

Computers that are three to four years old require the most work. The decrease in repairs required for five year old computers is probably due to the low number of those computers in use. Students will typically have their computer replaced after three or four years. Irrespective of the age of the notebook computers, the turn-around time for repairs is low, most being returned to the students on the same day. When a student's computer is being repaired the student is immediately given a replacement, in order that she may continue her lessons with minimal disruption.

One function of the Learning Technologies department is to actively search for software to assist students' learning. Any potential package is then tested on the different notebook models to ensure that is will perform adequately. When the software updates and hardware maintenance are considered, the insignificant correlation between the age of the computer and the development of higher order thinking skills is understandable. Certainly, there may be some angst from students enviously regarding their fellow students' latest acquisition, as shown by the data in Table 11.2 pertaining to the adequacy of the technology. This effect is minimal; the CLEI scale of Technology Adequacy is more concerned with the suitability of the technology applied to a specific task than its mechanical reliability.

11.5 TEACHER-STUDENT RELATIONSHIPS

11.5.1 Results

4.1 H_0: There is no significant correlation between teacher-student relationships and the development of critical thinking skills.

H_1: There is a significant correlation between teacher-student relationships and the development of critical thinking skills.

Table 11.27

Spearman's Correlations for the QTI Scales and EWCTET Score

QTI Scale		EWCTET Score
Leadership	Rho	0.126
Helping / Friendly	Rho	0.146
Understanding	Rho	0.228**
Student Responsibility	Rho	0.236**
Uncertainty	Rho	0.007
Dissatisfaction	Rho	-0.128
Admonishing	Rho	-0.228**
Strict	Rho	0.078

**Correlation is significant at the 0.01 level (1-tailed) N = 118

For the QTI Scales of Leadership, Helping/Friendly, Uncertainty and Dissatisfaction, accept the null hypothesis (H_0) that there is no significant correlation between teacher-student relationships and the development of critical thinking skills. For the QTI scales of Understanding, Student Responsibility and Admonishing, reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that there is a significant correlation between teacher-student relationships and the development of critical thinking skills.

4.2 H_0: There is no significant correlation between teacher-student relationships and the development of creative thinking skills.

H_1: There is a significant correlation between teacher-student relationships and the development of creative thinking skills.

Table 11.28

Spearman's Correlations for the QTI Scales and SCSM Score

QTI Scale		SCSM Score
Leadership	Rho	0.088
Helping / Friendly	Rho	0.031
Understanding	Rho	0.047
Student Responsibility	Rho	0.040
Uncertainty	Rho	0.000
Dissatisfaction	Rho	0.005
Admonishing	Rho	-0.068
Strict	Rho	-0.063

N = 136

Accept the null hypothesis (H_0) that there is no significant correlation between teacher-student relationships and the development of creative thinking skills.

4.3 H_0: There is no significant correlation between teacher-student relationships and the length of time within the environment.

H_1: There is a significant correlation between teacher-student relationships and the length of time within the environment.

Table 11.29

Spearman's Correlations for the QTI Scales and Length of Enrolment

QTI Scale		Length of Enrolment
Leadership	Rho	0.038
	N	141
Helping / Friendly	Rho	-0.072
	N	140
Understanding	Rho	-0.075
	N	141
Student Responsibility	Rho	-0.090
	N	140
Uncertainty	Rho	-0.049
	N	141
Dissatisfaction	Rho	0.017
	N	140
Admonishing	Rho	0.035
	N	141
Strict	Rho	-0.059
	N	140

Accept the null hypothesis (H_0) that there is no significant correlation between teacher-student relationships and the length of enrolment.

4.4 H_0: There is no significant correlation between teacher-student relationships and the age of the technology.

H_1: There is a significant correlation between teacher-student relationships and the age of the technology.

Table 11.30

Spearman's Correlations for the QTI Scales and the Age of the Technology

QTI Scale		Age of Technology
Leadership	Rho	0.111
Helping / Friendly	Rho	0.225**
Understanding	Rho	0.129
Student Responsibility	Rho	0.035
Uncertainty	Rho	-0.117
Dissatisfaction	Rho	-0.064
Admonishing	Rho	-0.045
Strict	Rho	-0.068

*Correlation is significant at the 0.01 level (1-tailed) N=137

Accept the null hypothesis (H_0) that there is no significant correlation between the QTI scales of Leadership, Understanding, Student Responsibility, Uncertainty, Dissatisfaction, Admonishing and Strict, and the age of the technology. Reject the null hypothesis (H_0) and accept the alternate hypothesis (H_1) that there is a significant correlation between the QTI scale of Helping/Friendly and the age of the technology.

11.5.2 Discussion of Results

Section 11.4.2 discusses the negative correlations betweens aspects of teacher-student relationships and the development of computing skills. Table 11.27 shows a similar trend, showing a significant positive correlation between the QTI scales Understanding and Student Responsibility, and the development of critical thinking skills. This is accompanied by significant negative correlations between the Admonishing scale and critical thinking skills. Correlations of the QTI and SCSM scales are shown in Table 11.31.

Table 11.31

Spearman's Correlations for the QTI and SCSM Scales

			SCSM	
QTI		Fluency	Flexibility	Originality
Leadership	Rho	0.025	0.096	0.146*
Helping/Friendly	Rho	-0.026	0.108	0.142
Understanding	Rho	-0.001	0.090	0.150*
Student Responsibility	Rho	0.070	-0.094	0.044
Uncertainty	Rho	0.012	-0.099	-0.121
Dissatisfaction	Rho	0.052	-0.067	-0.084
Admonishing	Rho	-0.001	-0.130	-0.113
Strict	Rho	-0.113	-0.113	-0.072

*Correlation is significant at the 0.05 level (1-tailed) N = 136

Again there are significant positive correlations for creative thinking and the positive human traits of Leadership and Understanding. These correlations relate to the creativity scale of Originality. Question Four of the SCSM measures creativity within the context of scientific imagination – using one's knowledge of science to envisage new situations. Data in Table 11.32 indicate that it is within this context that the correlation between leadership and creative thinking occurs.

Table 11.32

Spearman's Correlations for the QTI and SCSM Questions

QTI Scale		SCSM			
		Q1	Q2	Q3	Q4
Leadership	Rho	0.040	-0.004	0.007	0.146*
Helping/Friendly	Rho	0.021	-0.052	0.019	0.092
Understanding	Rho	-0.038	0.040	0.016	0.067
Student Responsibility	Rho	0.016	0.123	0.050	-0.055
Uncertainty	Rho	0.038	0.020	-0.030	-0.012
Dissatisfaction	Rho	-0.005	0.041	0.008	-0.055
Admonishing	Rho	-0.063	0.069	-0.074	-0.155*
Strict	Rho	-0.038	-0.109	-0.020	-0.071

*Correlation is significant at the 0.05 level (1-tailed) N = 135

Significant correlations exist between the scales of Leadership and Admonishing with the SCSM Question Four. This question can be divided into its Fluency, Flexibility and Originality components, as shown in Table 11.33.

Table 11.33

Spearman's Correlations for QTI Scales and SCSM Question Four Scales

QTI Scales		SCSM Q4 Scales		
		Fluency	Flexibility	Originality
Leadership	Rho	0.160*	0.135	0.226**
Admonishing	Rho	-0.096	-0.134	-0.186*

*Correlation is significant at the 0.05 level (1-tailed) **Correlation is significant at the 0.01 level (1-tailed)
N = 141

Table 11.33 shows that the scales of Fluency and Originality have significant correlations with the QTI scales of Leadership and Admonishing within Question Four of the SCSM. The positive correlation between the scores of students who perceive the environment to be one in which the teacher provides appropriate leadership is reinforced by the negative correlation between students scores and students who perceive the teacher to be reproachful. It appears that those students with greater creative thinking skills (with respect to Originality) perceive the technology-rich learning environment to be a setting that more closely approximates a socially constructivist classroom rather than a place that promotes traditional learning.

11.6 LENGTH OF TIME IN TECHNOLOGY-RICH ENVIRONMENTS

11.6.1 Results

5.1 H_0: There is no significant correlation between the length of time within technology-rich environments and the development of critical thinking skills.

H_1: There is a significant correlation between the length of time within technology-rich environments and the development of critical thinking skills.

Spearman's correlation for the length of enrolment and the EWCTET score is 0.036 (N=131). This is not significant at the 0.05 level, so the null hypothesis (H_0) should be accepted. There is no significant correlation between students' critical thinking skills and their length of time within the environment.

5.2 H_0: There is no significant correlation between the length of time within technology-rich environments and the development of creative thinking skills.

H_1: There is a significant correlation between the length of time within technology-rich environments and the development of creative thinking skills.

Spearman's correlation for the length of enrolment and the SCSM score is 0.049 (N=150). This is not significant at the 0.05 level, so the null hypothesis (H_0) should be accepted. There is no significant correlation between students' creative thinking skills and their length of time within the environment.

11.6.2 Discussion of Results

Sectin 11.6.1 demonstrates that there is no simple linear correlation between the length of enrolment in a technology-rich environment and the development of critical thinking skills. Closer analysis of the data provides more illumination.

In the researched learning environment there are intakes of new students each year. By dividing the Year Nine cohort into series of groups, statistical analysis between the series of groups is possible. The cohort was divided into students with less than one year in the environment and greater than one year; less than two years, greater than two years; and so on up to less than nine years, greater than nine years. Statistical correlations for these groups are shown in Table 11.34 and Figure 11.3.

Table 11.34

Spearman's Correlations for Length of Enrolment and EWCTET

		Length of Enrolment (Years)								
EWCTET		>=1	>=2	>=3	>=4	>=5	>=6	>=7	>=8	>=9
Rho	<1	0.080								
Rho	<2		-0.115							
Rho	<3			0.114						
Rho	<4				0.098					
Rho	<5					0.157*				
Rho	<6						0.157*			
Rho	<7							0.183*		
Rho	<8								0.183*	
Rho	<9									0.170*

*Correlation is significant at the .05 level (1-tailed). N = 132

Table 11.34 shows that there is a significant difference in the critical thinking skills (as measured by the EWCTET) of students who have been immersed in a technology-rich culture more than five years when compared to those who have been a part of the same culture for less than five years. This significant difference is maintained for students who have been a part of the culture for more than six, seven, eight and nine years. The cultural experiences from pre-school and/or kindergarten are not significant with respect to critical thinking in Year Nine.

Figure 11.3 provides a graphical representation of these correlations, from which a second order polynomial line-of-best-fit can be inferred. This describes the general trend between the length of time spent in the environment and the development of critical thinking skills.

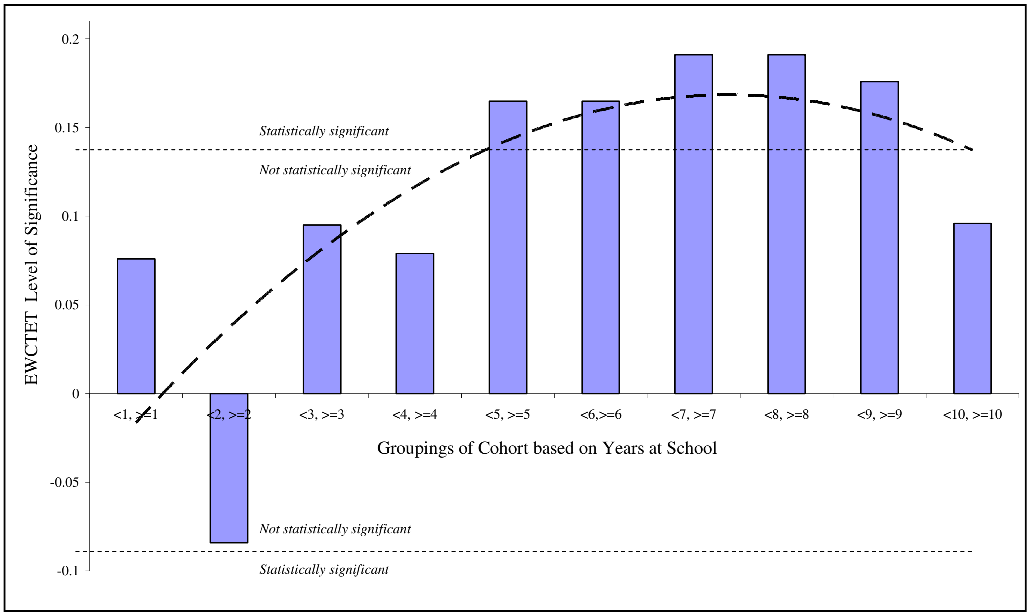


Figure 11.3. Correlations for EWCTET and the length of enrolment.

At this point it is worth returning to the work of Huitt (1999) described in Chapter Three. Huitt has identified conative activity as a link between the cognitive and affective domains, and considers it a critical motivating factor for the development of thinking. The above data indicate that there is a negative influence of the socio-cultural environment on the development of critical thinking for students with less than two years immersion in the environment. Adeyemo (2005) describes how a transition into secondary school is associated by a decline in academic achievement. This is not a new phenomena, having been previously reported by Maehr (1974).

Maehr describes how our social experiences affect the perception of our environment and therefore affects the acquisition of knowledge. As the social group to which a student belongs is changed, achievement also changes. In a more recent study, Tonkin and Watt (2003) have associated the decline in academic performance with both the transition to a new environment and the onset of adolescence. Given that all of the students in this research cohort are of the same age group, the adolescent factor is negated. There is greater influence from moving into a new environment. Students moving into this technology-rich environment have an added burden related to the use of technology in all of their classes. Being unfamiliar with the protocol of electronically delivered learning materials, and even unfamiliarity of the technology itself, initially detract from their ability to achieve higher cognition with the technology.

Data in Section 11.6.1 show that there is no significant correlation between the length of time spent in the technology-rich environment and the development of creative thinking skills. This pattern is repeated if correlations are made with all aspects of the SCSM, shown in Table 11.35.

Table 11.35

Spearman's Correlations for Length of Enrolment and SCSM Scales

		SCSM						
		Fluency	Flexibility	Originality	Q1	Q2	Q3	Q4
Length of Enrolment	Rho	-0.046	-0.024	0.025	-0.091	-0.075	0.037	-0.037

N = 149

Applying the same analysis as that shown in Table 11.34 to the analysis of creative thinking skills (Table 11.36) confirms the lack of significant correlation.

Table 11.36

Spearman's Correlations for Length of Enrolment and SCSM

		Length of Enrolment (Years)								
SCSM		>=1	>=2	>=3	>=4	>=5	>=6	>=7	>=8	>=9
Rho	<1	-0.087								
Rho	<2		0.001							
Rho	<3			-0.053						
Rho	<4				-0.048					
Rho	<5					-0.094				
Rho	<6						-0.125			
Rho	<7							-0.108		
Rho	<8								-0.074	
Rho	<9									-0.114

N = 150

This tends to support the arguments of Anderson and Krathwhol (2001), who place creative thinking as higher in order than critical thinking. Data in Tables 11.38, 11.39, 11.40, 11.41, 11.42 and Figure 11.3 suggest that the immersion in a technology-rich learning environment is able to promote the development of critical thinking skills but not to achieve the higher level of creative thinking.

11.7 AGE OF THE TECHNOLOGY

11.7.1 Results

6.1 H_0: There is no significant correlation between the age of the technology and the development of critical thinking skills.

H_1: There is a significant correlation between the age of the technology and the development of critical thinking skills.

Spearman's correlation for the age of the computers and the EWCTET scores is ¯0.050 (N=128). This is not significant at the 0.05 level, so the null hypothesis (H_0) should be accepted. There is no significant correlation between the age of the students' computers and the development of students' critical thinking skills.

6.2 H_0: There is no significant correlation between the age of the technology and the development of creative thinking skills.

H_1: There is a significant correlation between the age of the technology and the development of creative thinking skills.

Spearman's correlation for the age of the computers and the SCSM scores is -0.014 (N=145). This is not significant at the 0.05 level, so the null hypothesis (H_0) should be accepted. There is no significant correlation between the age of the students' computers and the development of students' creative thinking skills.

11.7.2 Discussion of Results

Section 11.4.2 describes the significant correlation between students' length of enrolment and the development of their computer skills and the significant correlation between students' length of enrolment and the development of their critical and creative thinking skills. That section also explains the lack of correlation between students' computer skills and the age of their computers. It would seem reasonable that there is no significant correlation between the development of higher order skills and the age of the technology employed.

Data in Section 11.7.1 show Spearman's correlations for critical and creative thinking test scores and the ages of students' computers. When considered together, the data show that this hypothesis is supported with regards to critical and creative thinking. The SCSM data for Fluency, Flexibility and Originality are shown in Table 11.37.

Table 11.37

Spearman's Correlations for the Age of Computers and Fluency, Flexibility and Originality SCSM Scores

		SCSM Scales		
		Fluency	Flexibility	Originality
Age of Computer	Rho	-0.019	-0.088	-0.015

N = 145

Data in Table 11.37 indicates that there are no significant, correlations between the age of the computer and the development of Fluency, Flexibility or Originality.

There are significant correlations between the development of computer skills, critical thinking skills and the length of time spent in the technology-rich environment. There are no significant correlations between the development of computer skills and creative thinking skills. The influence of time within the environment is not as clear.

11.8 DEVELOPMENT OF CREATIVE THINKING SKILLS

11.8.1 Results

7.1 H_0: There is no significant correlation between students' development of creative thinking skills and their development of critical thinking skills.

H_1: There is a significant correlation between students' development of creative thinking skills and their development of critical thinking skills.

Spearman's correlation for the EWCTET and SCSM total scores is 0.086 (N=125). This is not significant at the 0.05 level so the null hypothesis (H_0) should be accepted. There is no significant correlation between students' development of critical and creative thinking skills.

11.8.2 Discussion of Results

Data in Section 11.8.1 indicate that there is no significant correlation between the development of critical and creative thinking skills. Anderson and Krathwohl (2001) place creative thinking skills at a higher level than critical thinking. Possibly more time is needed within the learning environment for creative skills to develop. It is also possible that this learning environment implicitly places a greater emphasis of critical thinking skills. Alternatively it is possible that other factors, such as the influence of heredity, are greater than the influence of environment for the development of creative thinking. Baker, Rudd, and Pomeroy (2001) regard genetics as both a catalyst and inhibitor of higher order thinking. They cite an array of references that either support or oppose a high degree of genetic influence over creativity; an idea that is continued in a later article (Baker, Rudd, & Pomeroy, 2002). However, Cotton (2001) maintains that skills, therefore thinking skills, can be taught, as described in Chapter Two.

Table 11.38 shows the correlations for the SCSM scales and critical thinking. Included are correlations for critical thinking with Questions One, Two, Three and Four of the SCSM.

Table 11.38

Spearman's Correlations for Fluency, Flexibility, Originality and Critical Thinking

		SCSM Scales			SCSM Questions			
		Fluency	Flexibility	Originality	1	2	3	4
EWCTET Total Score	Rho	0.053	0.020	0.067	0.178*	0.020	0.054	0.158*

*Correlation is significant at the 0.05 level (1-tailed). N = 125

Table 11.38 shows that there is no significant correlation between critical thinking skills and the creativity scales of Fluency, Flexibility or Originality, although there is a significant correlation between the EWCTET scores and the SCSM Question One and Question Four scores. Questions One through to Four of the SCSM measure these scales within different contexts. Question One requires students to list all of the scientific uses for a piece of glass. This requires a working knowledge of scientific equipment procedures, and the ability to mentally distinguish between scientific and non-scientific uses. This question measures students' Fluency, Flexibility and Originality within the milieu of scientific knowledge. The correlations between EWCTET scores and the SCSM scale scores for Question One are shown in Table 11.39.

Table 11.39

Spearman's Correlations for EWCTET Scores and SCSM Question One Scales

	SCSM Scales for Question 1		
	Fluency	Flexibility	Originality
EWCTET Total Score Rho	0.116	0.249**	0.136

**Correlation is significant at the 0.01 level (1-tailed). N = 125

It can be seen from Table 11.39 that there is a significant correlation between the EWCTET score and the Flexibility component of SCSM Question One.

Question Four measures Fluency, Flexibility and Originality within the context of scientific imagination. The correlations between EWCTET scores and the SCSM scale scores for Question Four are shown in Table 11.40.

Table 11.40

Spearman's Correlations for EWCTET Scores and SCSM Question Four Scales

	SCSM Scales for Question 4		
	Fluency	Flexibility	Originality
EWCTET Total Score Rho	0.104	0.107	0.131

N = 131

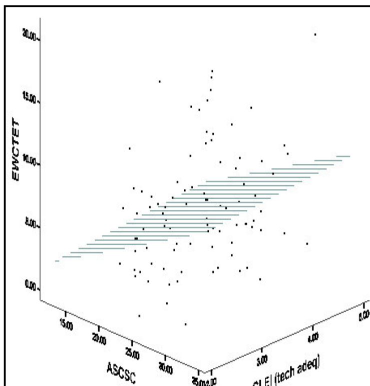
When the scales are considered independently there are no significant correlations between the EWCTET and Fluency, Flexibility and Originality within the context of scientific imagination. Creative thinking needs to considered holistically, in this context, for the correlation to be evident. It would appear that in order to use scientific knowledge in a creative way, students must first attain a significant level of critical thinking skills.

11.9 THREE-DIMENSIONAL ANALYSIS

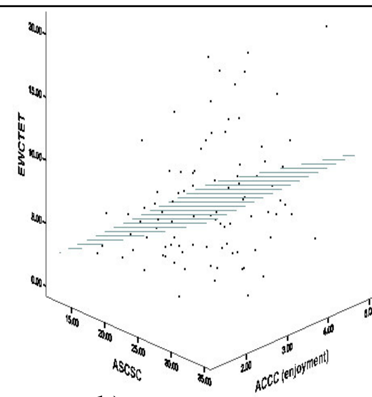
Section 11.2 through to Section 11.7 discussed the correlations that exist between the different aspects of the technology-rich learning environment and the development of higher order thinking skills. These correlations are bivariate, examining only two aspects of the environment at one time. No two aspects function in isolation of the remaining aspects. This section examines the relationships between three environmental factors at one time. Given the number of scales within each of the six instruments used, the analysis of all possible permutations would be quite lengthy, and unnecessary. Only those factors shown to have significant bivariate correlations are included.

The CLEI, ACCC and QTI measure the three dimensions of the learning environment described by Moos (1974, in Fraser, 1998a, p. 530) and outlined in Chapter Five. These are represented by the Technology Adequacy scale of the CLEI; Enjoyment from the ACCC; and Leadership and Understanding from the QTI. Generic computer skills are represented by the total score for the ASCSC. Higher order thinking skills are represented by the total score for the EWCTET and the Originality score for the SCSM.

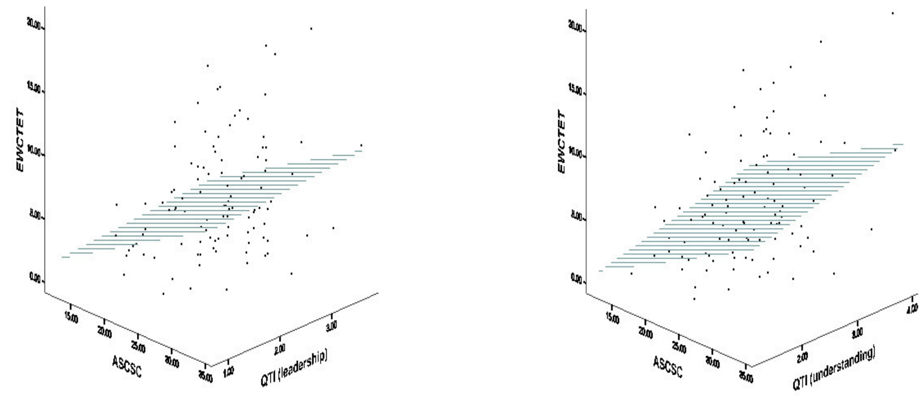
Three-dimensional graphs that show the relationships between critical and creative thinking with permutations of the CLEI, ACCC, QTI and ASCSC are shown in Figures 11.4 and 11.5.



a)



b)



a) EWCTET vs CLEI vs ASCSC b) EWCTET vs ACCC vs ASCSC
c) EWCTET vs QTI(Leadership) vs ASCSC d) EWCTET vs QTI(Understanding) vs ASCSC

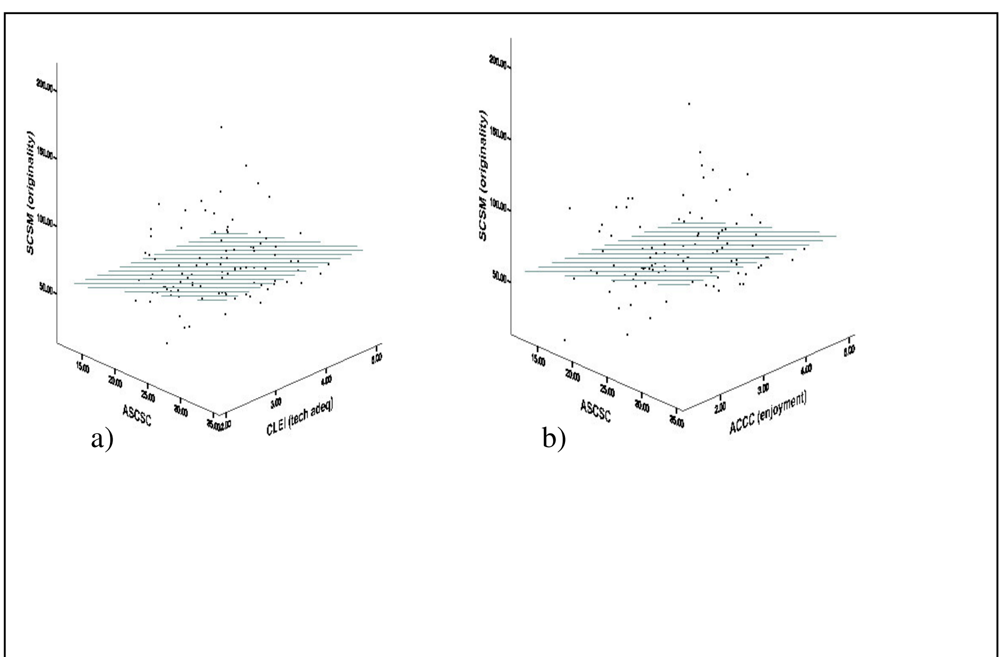
Figure 11.4. Environmental effects on the development of critical thinking skills.

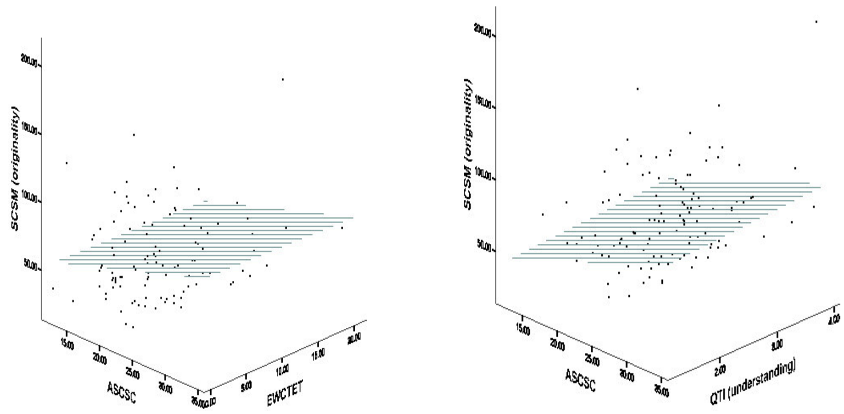
Figure 11.4 demonstrates the affects of students' computer skills, their perceptions of the learning environment, their attitudes towards computing and the teacher-student relationships, on the development of critical thinking skills. The planes-of-best-fit allow the following equations to be derived:

1. EWCTET = $^{-}$2.58 + 0.34ASCSC + 0.35CLEI
2. EWCTET = 1.60 + 0.34ASCSC + 0.06ACCC
3. EWCTET = $^{-}$2.54 + 0.34ASCSC + 0.35QTI(Leadership)
4. EWCTET = $^{-}$4.15 + 0.31ASCSC + 1.14QTI(Understanding)

These can be reduced to

5. EWCTET = $^{-}$1.92 + 0.33ASCSC + 0.09CLEI + 0.02ACCC + 0.37QTI





a) SCSM vs CLEI vs ASCSC b) SCSM vs ACCC vs ASCSC
c) SCSM vs QTI(Leadership) vs ASCSC d) SCSM vs QTI(Understanding vs ASCSC

Figure 11.5. Environmental effects on the development of creative thinking skills.

Figure 11.5 demonstrates the affects of students' computer skills, their perceptions of the learning environment, their attitudes towards computing, their level of critical thinking and the teacher-student relationships, on the development of creative thinking skills. The planes-of-best-fit allow the following equations to be derived:

6. $SCSM = 42.62 + 1.61ASCSC + {}^{-}2.96CLEI$
7. $SCSM = 40.99 + 1.70ASCSC + {}^{-}3.39ACCC$
8. $SCSM = 18.95 + 2.04ASCSC + 1.56QTI(Leadership)$
9. $SCSM = 16.77 + 2.00ASCSC + 2.57QTI(Understanding)$

These can be reduced to

10. $SCSM = 29.83 + 1.84ASCSC -0.07CLEI - 0.85ACCC + QTI$

Equations 5) and 10) should not be seen as a means of mathematically determining a student's level of higher order thinking. They are used to represent the relative influence of different environmental factors on the development of critical or creative thought.

11.10 SUMMARY

The data presented in Chapters Nine and Ten form the basis on which the learning environment can be analysed, and the relationships between the environmental factors are established. There is, necessarily, some overlap within these sections. For example, elements of discussing the role of time spent in the environment bisect a discussion of the effects of the age of the technology within the environment. Where relevant the discussions draw on the theoretical perspectives presented in the earlier chapters.

Reliability of the instruments is inferred from Cronbach's alpha coefficient. A coefficient of 0.6 is generally considered to indicate reliable data with respect to internal consistency (Garson, 2006). Other researchers, for example De Vellis (1991) and Cook and Fairweather (2003), maintain that values greater than 0.5 are acceptable.

Administration of the CLEI, ACCC, QTI, ASCSC, EWCTET and the SCSM has resulted in a number of significant correlations that together describe the relationships within the learning environment. Social factors, such as students' enjoyment and teacher-student interactions have been correlated with a development in computer skills. Significant correlations have been shown to be present between time spent in the technology-rich environment and the development of computer skills and critical thinking skills. Based on the available data, time in the environment does not seem to affect the development of creative thinking skills. These social environmental factors also correlate with the development of critical thinking, and with the originality component of creative thinking.

Correlations have been shown to exist between students' computer skills, particularly computer programming skills, and the development of critical thinking skills. Similar correlations are evident between students' computer skills and their development of all three scales of creative thinking.

CHAPTER 12

CONCLUSIONS, LIMITATIONS AND IMPLICATIONS OF THE RESEARCH

12.1 INTRODUCTION

In Chapter One it is stated that there has been little data collection with respect to higher order thinking in computer-based learning environments (Maor & Taylor, 1993; Roth & Lawless, 2001). This thesis adds to the data. Furthermore, the concern of Agnew (2002) related to the observation and measurement of higher order thinking skills is addressed.

Technology allows students to explore their subjects in greater breadth and depth. An unprecedented amount of data is available to students via CDs, subject specific software and, importantly, the Internet. Classroom observations show that simply providing greater access to subject specific content does not improve students' thinking, but careful use of the content does.

Teachers do not all have the same computing skills as their students. Neither do they need these skills. Socially constructivist learning necessitates collaboration between the students, and it is the employment of their computer skills that assists the students with their learning. Well developed 'productivity tool' skills allow students to quickly address lower level cognitive activities thus allowing more time, and with a broader base, to explore high order thinking activities.

12.2 ANSWERS TO THE RESEARCH QUESTIONS

The questions proposed in Chapter One were addressed by administering a variety of research instruments. The results are presented and analysed in Chapters 9, 10 and 11. This section draws on the data, and its analysis, to answer the original questions.

12.2.1 Question One

1. What is the relationship between student perceptions of technology-rich learning environments and
    1.1. their attitude towards computers?
    1.2. their level of technological skill?
    1.3. the student-teacher relationship within that learning environment?
    1.4. the development of critical higher order thinking skills?
    1.5. the development of creative higher order thinking skills?
    1.6. length of time within the environment?
    1.7. the age of the technology?

Students who perceive their learning environment to be one in which technology is well integrated, and adequate, have a positive attitude towards computers and towards their classes in which computers are used. This includes positive relationships with their teachers. They achieve higher levels of computer skills, particularly skills related to computer programming. These students also achieve higher levels of critical thinking, and higher levels of creative thinking specific to originality within the context of sensitivity towards scientific issues. The students' perceptions of the technology components of the learning environment are not affected by the length of time in which the students have been in that environment, nor by the age of the technology.

12.2.2 Question Two

2. What is the relationship between student attitudes towards computers and the
    2.1. level of technological skill?
    2.2. student-teacher relationship within the learning environment?
    2.3. development of critical higher order thinking skills?
    2.4. development of creative higher order thinking skills?
    2.5. length of time within the environment?
    2.6. age of the technology?

Students with a positive attitude towards computers, their computer classes and their teachers achieve higher levels of computer skills. This positive attitude does not necessarily increase their achievment of higher order thinking skills. It does allow them to meld conative and cognitive functions, which allows for the development of higher order thinking.

Generally, there is no correlation between the students' attitudes and the length of time within the technology-rich environment. However, as their time in the environment increases, so does their perception of the usefulness of computers within their education. The age of the technology does not affect their attitudes towards their computer classes.

12.2.3 Question Three

3. What is the relationship between students' computer skills and the
    - 3.1. student-teacher relationship within those learning environments?
    - 3.2. development of critical higher order thinking skills?
    - 3.3. development of creative higher order thinking skills?
    - 3.4. length of time within the environment?
    - 3.5. age of the technology?

There are significant correlations between students' attainment of computing skills measured by the ASCSC, and their perceptions of the learning environment measured by the QTI. These correlations broach lower order and higher order computing proficiencies. Students who perceive the learning environment to contain higher degrees of teacher leadership, helpfulness and friendliness, supported by significant negative correlations for uncertainty, dissatisfaction, admonishment and strictness, score higher in the ASCSC. This correlation is strongest for students who gain higher scores for the higher order skills embraced by computer programming.

There is a significant correlation between students' computers skills measured by the ASCSC and their level of critical thinking skills measured by the EWCTET. The correlation exists between critical thinking skills and higher order computer skills, represented by the ASCSC scales of Internet and Programming. Students with better computing skills demonstrate a higher level of critical thinking.

There are significant correlations between students' computer skills and their creative thinking skills. These correlations span the three scales of Fluency, Flexibility and Originality as measured by the SCSM, and both low and high order computing skills. There are significant, positive correlations between lower order computing skills, determined by the ASCSC Productivity Tools scale, and the creative thinking scales of Fluency and Flexibility. There are also significant, positive correlations between higher order computer skills, as determined by the ASCSC scale of Programming, and the creative thinking scale of Originality.

There is a significant, positive correlation between the length of time that students spend in the technology-rich environment and their development of computer skills. As an individual's computer skills do not affect their length of enrolment, it can be concluded that the correlation shows a causal relationship, in which the length of time a student is enrolled in the technology-rich environment affects their development of technology skills. Regular updating of software, and a well-established hardware maintenance program, mean that there is no significant correlation between the age of the technology and the development of computer skills.

12.2.4 Question Four

4. What influence do teacher-student relationships have with respect to the
   4.1. development of critical higher order thinking skills?
   4.2. development of creative higher order thinking skills?

Students generally enjoy the computing aspects of this learning environment and appreciate their computer skills classes. The learning environment is regarded as a friendly, teacher-tolerant atmosphere that has characteristics found within a social constructivist environment. Those students that perceive the learning environment to be socially constructivist are those who more often display higher order thinking skills, when their critical and creative thinking is measured by the EWCTET and SCSM.

12.2.5 Question Five

5. Is there a significant correlation between the length of time spent within technology-rich environment and the development of
   5.1. critical higher order thinking skills?
   5.2. creative higher order thinking skills?

There is a significant, non-linear relationship between the length of time spent within a technology-rich environment and the development of critical thinking skills. An initial delay in the effect of the technological aspects of the environment becoming significant could be due to socio-cultural factors associated with adapting to new situations.

There is no significant correlation between the length of time spent in a technology-rich environment and the development of creative thinking skills.

12.2.6 Question Six

6. Is there a significant correlation between the age of the technology and the development of
   6.1. critical higher order thinking skills?
   6.2. creative higher order thinking skills?

There is no significant correlation between the age of the technology and the development of critical, or creative, higher order thinking skills. Students immersed in this environment for more than three years generally replace their notebooks with newer models. Those who do not are well supported with regards to software and hardware issues. In this regard, the data reinforce the previous conclusion; prolonged immersion in a technology-rich environment can increase the level of critical thinking skills.

12.2.7 Question Seven

7. What is the relationship between students' development of creative higher order thinking skills and their development of critical higher order thinking skills?

There is a significant correlation between the development of critical thinking skills and creative thinking skills, as measured by the EWCTET and SCSM within a technology-rich environment. A positive correlation occurs between critical thinking skills and the use of scientific knowledge. It cannot be definitively stated that this is a correlation of critical thinking with the specific scales of Fluency, Flexibility or Originality. Based on the instruments used it would appear to be a correlation between critical thinking skills and the Flexibility scale, within the context of the creative application of scientific knowledge.

12.2.8 Summary

These seven questions and their answers elaborate the key questions "What is the relationship between technology-rich learning environments and the development of higher order thinking skills?" and "To what extent are higher order thinking skills demonstrated by students in a technology-rich environment?"

Technology integration enhances social constructivist learning environments. Given time, students become competent and confident with using technology, as do their teachers. It provides a means by which students can collaborate, synchronously and asynchronously, with each other and with their teachers. This allows challenging and testing of concepts to occur, resulting in a deeper understanding of the particular subject.

The use of applications packages allows students to quickly and accurately process data, and therefore create knowledge. Time saved permits more time to be spent exploring specific subjects at deeper levels; exploration which is further enhanced by using the technology.

Teaching specific skills related to computer programming enhances students' attainment of higher order thinking skills. The programming skills include developing an understanding of Boolean logic, top-down approaches to solving problems and exploring data manipulation from novel dimensions. The development of computer skills within a socially constructivist, technology-rich environment allows students to attain higher order thinking skills on par with tertiary level students.

12.3 LIMITATIONS

Chapter One outlines the conceptual limitations of this research. By conducting the inquiry as a case study this research is not subjected to repetition. Certainly, data were collected from approximately 150 students, but each instrument was only implemented once. Different results, and therefore possibly different conclusions, that could result from repetitive data collection remain unknown. As each case is unique, wider generalisations should be treated with caution. This section focusses on research limitations that relate to the specific instruments used.

12.3.1 Classroom Observations

A number of teachers were approached for permission to observe their classes. While most were willing to oblige, reticence was not absent. Some of the teachers who elected not to participate cited reasons such as "not using much technology at this point". Teachers who allowed classroom observations were typically more confident in their use of technology, and used it in a variety of ways. There is a possibility that this could skew the level of technology implementation reported, hence over-rating the technological nature of the learning environment.

12.3.2 Computer Laboratory Environment Inventory and Attitude towards Computers and Computer Classes

These instruments were originally designed for use in the tertiary environment. The validation and reliability of these instruments within the tertiary sector do not necessarily apply to the current research environment. While their degree of reliability has been measured, their validity has not. Removal of scales deemed irrelevant to this research, and the minor editing of elements within the other scales, may have affected the validity of these instruments.

12.3.3 Australian Schools Computer Skills Competition

Computer skills can be considered as mental and practical activities. A test that consists of multiple choice and short answers questions can only address practical questions in a limited way. Questions that require reading and writing, but no "hands-on" computer activities could favour students who are predisposed to the former.

Data pertaining to the validity and reliability of this instrument are not released by the authors. It is not known if such data are gathered on a national basis. Each year the questions in this test are redesigned. The same question is never used twice. Whilst the reliability can be determined at a school level, the annual changes make comparisons over several years a dubious activity.

12.3.4 Ennis' Weir Critical Thinking Essay Test

This instrument requires students to critically respond to the arguments put forward in a "letter to the editor" concerning street-parking. Year Nine students in Western Australia are at least two years away from gaining their driver's licenses. Notwithstanding the instrument tests critical thinking, a limited knowledge of the subject matter could affect the students' ability to correctly identify fallacious arguments.

12.3.5 Scientific Creativity Structure Model

The main weakness of this instrument is its newness. There is little global data available when compared to other instruments such as the TTCT. While this does not detract from its validity or reliability, some researchers may not consider this instrument to be credible.

The SCSM measures three scales of creative thinking – Fluency, Flexibilty and Originality. The scale of Elaboration is ignored. Attempts to infer Elaboration from Flexibility would diminish the validity of the questions designed to measure Flexibility.

Within the context of this study, ‘technology’ is primarily concerned with computers. The use of other forms of technology such as digital camera, data logging probes, iPods, etc, has not been addressed in detail. The implementation of such technology by students may impact on their development of creative thinking skills.

12.4 IMPLICATIONS

12.4.1 Developing Pedagogy and Classroom Applications

Schools should endeavour to integrate technology across all of the learning areas. This will allow students to apply technology to the attainment of higher levels of cognition within specific contexts. At the time of writing (2006) this is particularly relevant in Western Australia, where teachers are rebuilding their teaching-learning programs for the emerging WA Courses of Study.

If students are to apply computer-based technology to their studies they must be given the opportunity to develop appropriate computer skills. As demonstrated by the data, this does not necessarily require the latest model computers. The power of computers in education lies in embedding them in the curriculum and not using them as embellishments.

While technology skills include the lower level manipulation of applications programs, they include developing higher order skills such as computer programming. Using productivity tools effectively allows subjects to be explored in greater detail. Computer programming develops skills in logic, critical thinking and creative thinking. This research indicates that the technology has a greater influence on critical thinking. Application of computing to assist the development of creative thinking needs to be further developed. Consideration should also be given to the establishment of technology-based teaching-learning programs to develop generic higher order thinking skills.

Chapter Three describes how our methods of learning provide an evolutionary advantage. The capacity to think at higher levels allows us to adapt to new environments, survive and flourish. This has not been accompanied by an evolution in what is taught. The application of computer technology to the development of higher order thinking means that it is time for teaching to evolve. Students are able to understand topics previously considered the domain of universities. For example, computer programming. This learning ability needs to be addressed by rethinking the teaching process.

12.4.2 Further Research

A large amount of data were collected using six research instruments. Figure 5.1 shows how two of these instruments, the CLEI and ACCC, evolved. Originally designed for tertiary computer laboratory environments, these instruments were adapted for a 1:1 notebook computer environment at secondary school level. The evolutionary process needs to continue, to design and test an instrument specifically for 1:1 computer environments in secondary schools, which are gaining popularity.

As stated in Chapter One, the SCSM is a relatively new instrument. This does not detract from its validity or reliability but it does limit the amount of data that has been collected. Calculations of originality are based on percentile data from the relevant research environment. Further implementation of this instrument could provide a much greater pool of responses. This would allow for the establishment of an originality scoring key, similar to that developed by Torrance (1974).

The EWCTET determines a student's general level of critical thinking based on the responses to an argument that allows different aspect of critical analysis to be applied. The test only allows each aspect to be explored once, with the exception of recognising logical argument, which is examined twice. A refinement would be to develop a test that allows different aspects to be examined several times. This would permit the internal reliability to be calculated in the same way as the other instruments, and it would allow students to present their critical thinking in a range of contexts.

Data in Chapter 11 show significant correlations between ACCC and SCSCM scales but not between the ACCC scales and the EWCTET. This could imply that critical thinking lies above creative thinking in a cognitive hierarchy. This contradicts other data. For example, the correlations between the CLEI scales and the EWCTET and SCSM. It also goes against the beliefs of Anderson and Krathwohl (2001) who place creativity above critical analysis. The contradiction suggests that the cognitive hierarchy is not linear, and may include branching into two pathways of critical and creative cognition. This idea needs to be further explored to help in the achievement of both sets of higher order thinking skills.

The research cohort consisted of 150 Year Nine students in an independent, Uniting Church affiliated all-girls' school. Other learning environments, for example, co-educational State schools, need to be examined before generalising the results. Within the current research environment the differences between sub-cultures could be examined, providing more information about the effects of the learning environment. One such sub-culture would be the division between students who are day-girls or boarders.

Set within an environment that strives towards constructivism, this research has not attempted to measure the effects of computers used within other educational paradigms. However, the analyses presented in Chapter 11, Sections 11.2, 11.3 and 11.5, demonstrate that students perceive the same environment differently, and within this environment different students demonstrate different levels of computer skills and higher order thinking skills. Further research could be based on Gardner's theory of multiple intelligences (Gardner, 1993). This could include exploring the relationships between students with different learning styles using computers as learning tools.

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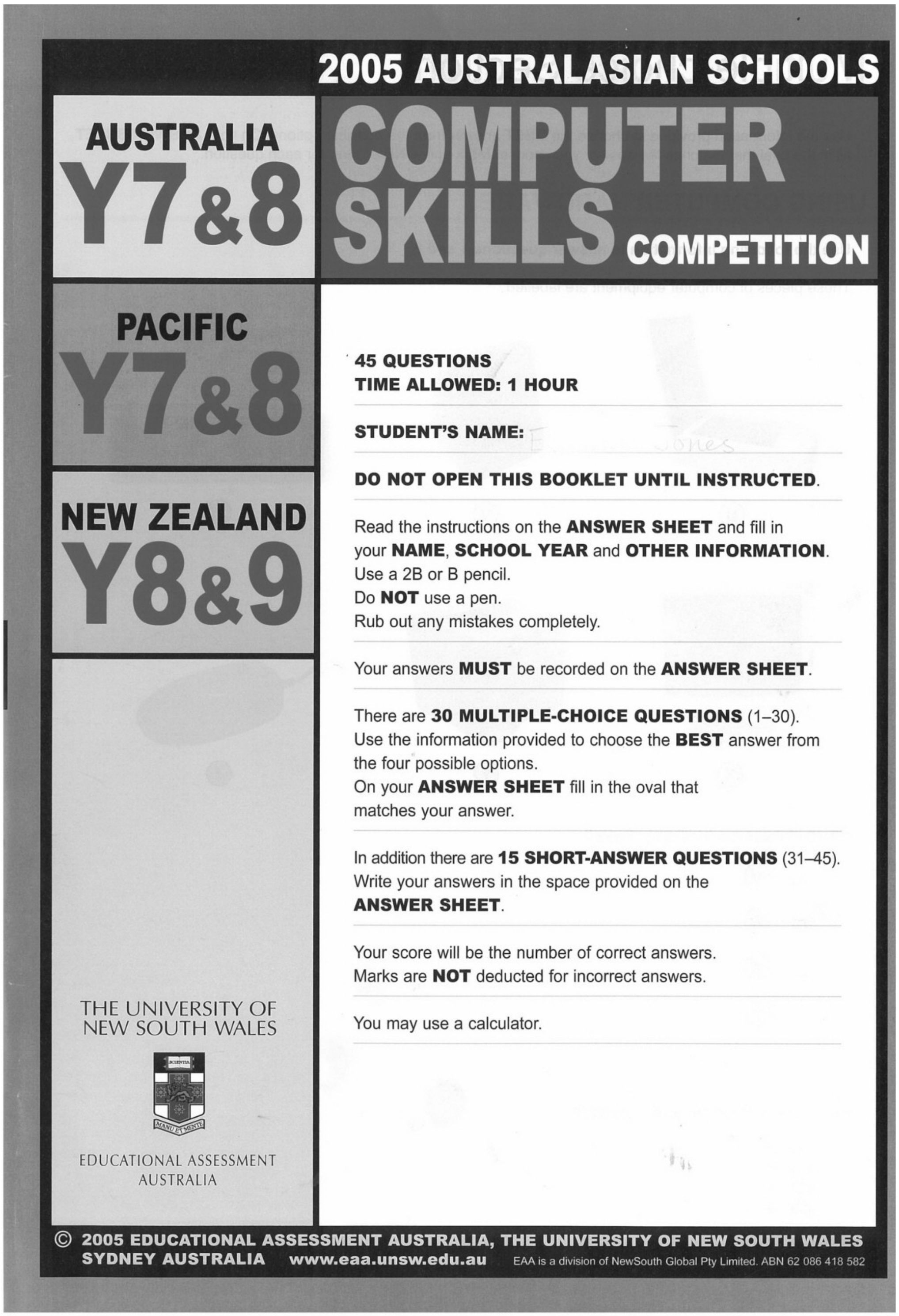
APPENDICES

APPENDIX 1

AUSTRALIAN SCHOOLS COMPUTER SKILLS COMPETITION

Reproduced with the permission of the Educational Assessment Australia Management Committee, University of New South Wales



2005 AUSTRALASIAN SCHOOLS

COMPUTER SKILLS COMPETITION

AUSTRALIA Y7 & 8

PACIFIC Y7 & 8

NEW ZEALAND Y8 & 9

45 QUESTIONS
TIME ALLOWED: 1 HOUR

STUDENT'S NAME:

DO NOT OPEN THIS BOOKLET UNTIL INSTRUCTED.

Read the instructions on the **ANSWER SHEET** and fill in your **NAME**, **SCHOOL YEAR** and **OTHER INFORMATION**.
Use a 2B or B pencil.
Do **NOT** use a pen.
Rub out any mistakes completely.

Your answers **MUST** be recorded on the **ANSWER SHEET**.

There are **30 MULTIPLE-CHOICE QUESTIONS** (1–30).
Use the information provided to choose the **BEST** answer from the four possible options.
On your **ANSWER SHEET** fill in the oval that matches your answer.

In addition there are **15 SHORT-ANSWER QUESTIONS** (31–45).
Write your answers in the space provided on the **ANSWER SHEET**.

Your score will be the number of correct answers.
Marks are **NOT** deducted for incorrect answers.

You may use a calculator.

THE UNIVERSITY OF NEW SOUTH WALES

EDUCATIONAL ASSESSMENT AUSTRALIA

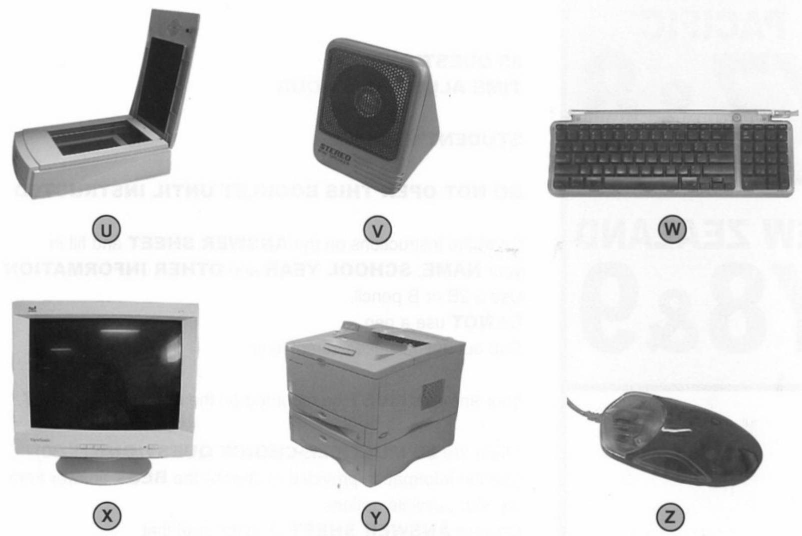
Multiple-choice Section

Use the information provided to choose the **BEST** answer from the possible options. On your **ANSWER SHEET** fill in the oval that matches the answer you choose. Mark only **ONE** answer for each question.

USING COMPUTER HARDWARE

Use the following information to answer questions 1 and 2.

These pieces of computer equipment are labelled.



1 Which of these is a hard-copy device?

(A) V

(B) W

(C) X

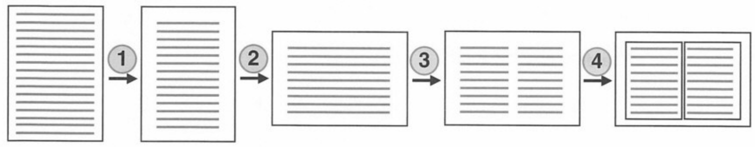
(D) Y

2 How many of these are output devices?

(A) 1
(B) 2
(C) 3
(D) 4

USING SOFTWARE PACKAGES — GENERAL

3 Carl made the following changes to the layout of a document.



In which step did he change the page orientation from portrait to landscape?

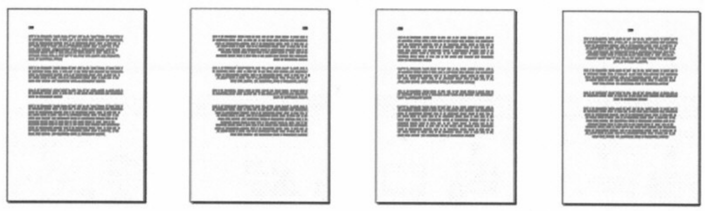
(A) 1

(B) 2

(C) 3

(D) 4

4 Which of the following images shows a page where the text has been justified?



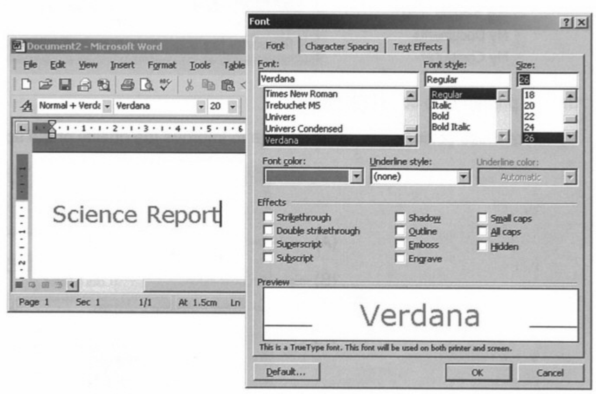
(A) (B) (C) (D)

USING SOFTWARE PACKAGES — WORD PROCESSING

5 Sue opened this dialogue box.

If Sue clicks on OK, what will be the size of the words "Science Report"?

(A) 18
(B) 20
(C) 22
(D) 26

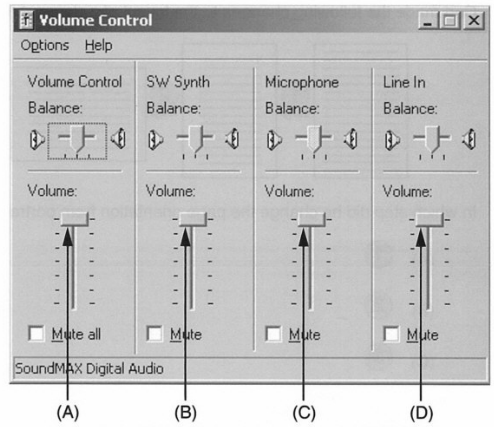


USING COMMON OPERATING SYSTEMS

6 Maria is playing a CD on her computer.

She finds that the volume of the CD is too loud.

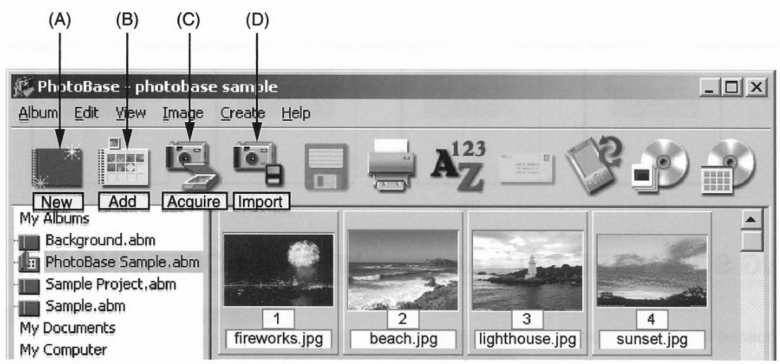
Which slider should Maria drag down to make the music less loud?



USING SOFTWARE PACKAGES — GRAPHICS

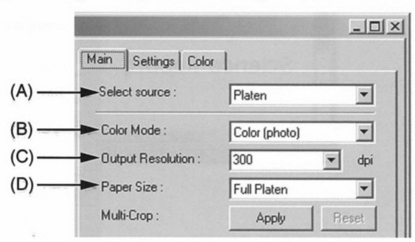
7 Jack is using a Photo Album program.

Which of these buttons should Jack click to scan a photo?



8 Jack is preparing to scan the photo.

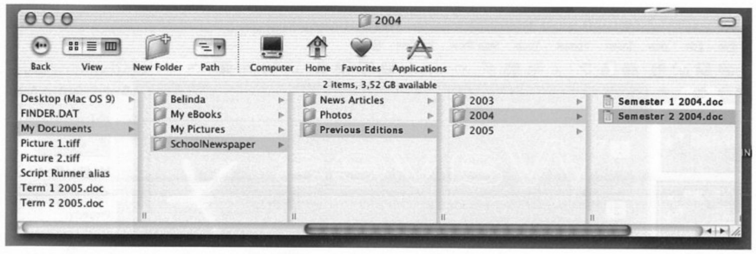
Which of these settings should he change to improve the quality of the scanned image?



USING COMMON OPERATING SYSTEMS

Use the following information to answer questions 9 and 10.

This is a screen shot of a window showing all the folders in My Documents.



9 Which folder has its contents displayed in the far right-hand side of the window?

(A) My Documents
(B) School Newspaper
(C) Previous Editions
(D) 2004

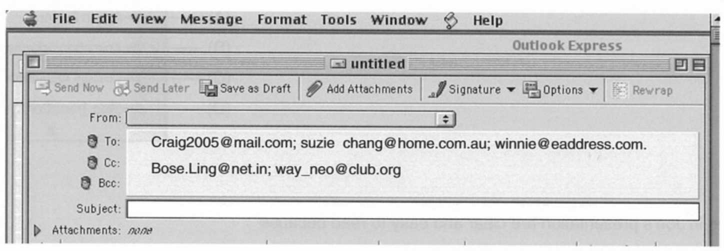
10 If the School Newspaper folder were deleted, how many other folders, visible in the screenshot above, would also be deleted?

(A) 2
(B) 3
(C) 6
(D) 8

INTERNET SKILLS — EMAIL

Use the following information to answer questions 11 and 12.

Lisa wanted to send an email to five of her friends but she made some mistakes when typing their email addresses.

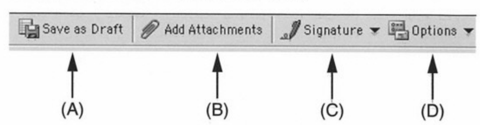


11 How many of the addresses above have an **<u>INCORRECT</u>** email address format?

(A) 1
(B) 2
(C) 3
(D) 4

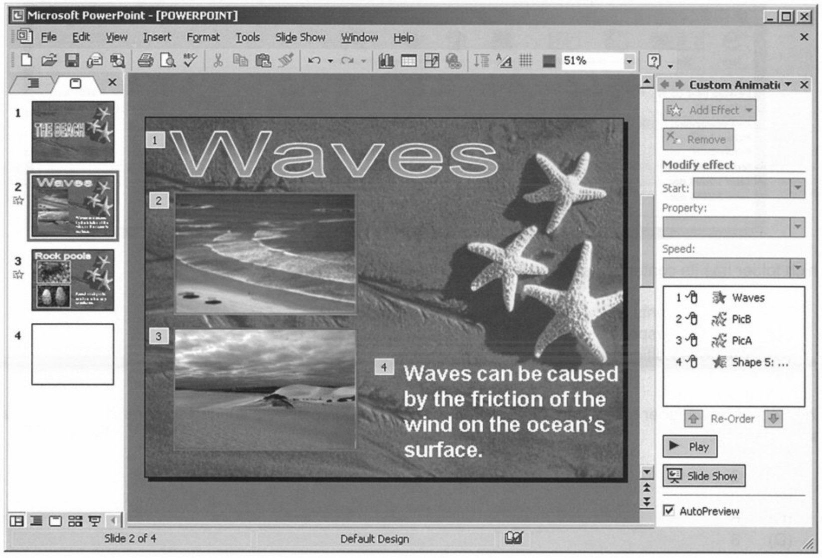
12 Lisa wanted to send a JPEG image with the email.

Which of these icons should she click?



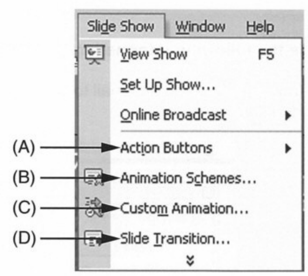
Use the following information to answer questions 13 and 14.

Joe is creating this slide show presentation.



13 In slide shows the slides can be advanced manually or automatically.

Which option from the Slide Show menu can Joe use to set the slides to advance automatically?



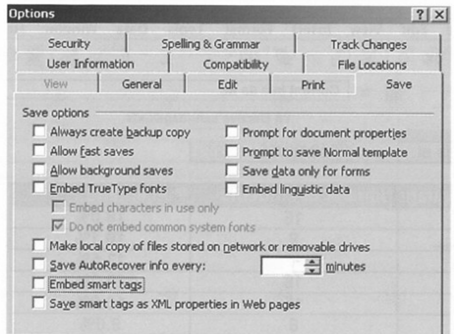
14 The slides in Joe's presentation are clear and easy to read because

(A) different transitions have been added between slides.
(B) they contain a limited amount of text and graphics.
(C) they include charts and tables.
(D) the last slide is empty.

USING SOFTWARE PACKAGES - GENERAL

Use the following information to answer questions 15 and 16.

Ling was working on a science assignment that she did not want to lose if her computer crashed unexpectedly. She opened the dialogue box shown.



15 Which box should be checked so that her assignment is automatically saved?

(A) Always create backup copy
(B) Allow fast saves
(C) Allow background saves
(D) Save AutoRecover info every:

16 Ling would also like to protect her document with a password.

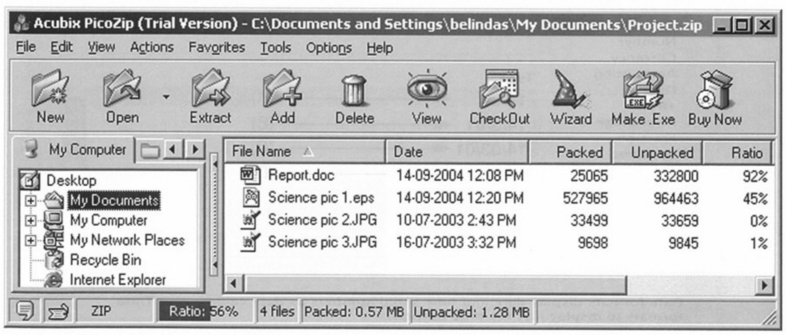
Under which tab can she set a password?

(A) Security
(B) Track Changes
(C) User Information
(D) General

USING COMMON OPERATING SYSTEMS

Use the following information to answer questions 17 and 18.

Mike opened an archive folder.



17 What is the name of the archive folder?

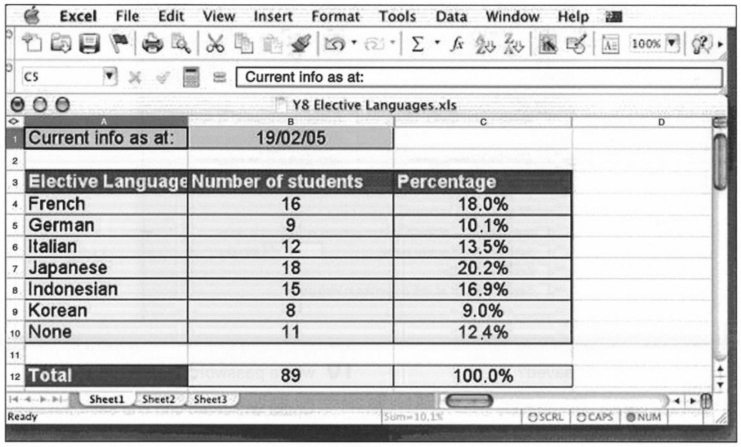
(A) PicoZip
(B) Project
(C) My Documents
(D) Report

18 Which file has been compressed the most?

(A) Report
(B) Science pic 1
(C) Science pic 2
(D) Science pic 3

Use the following information to answer questions 19 to 21.

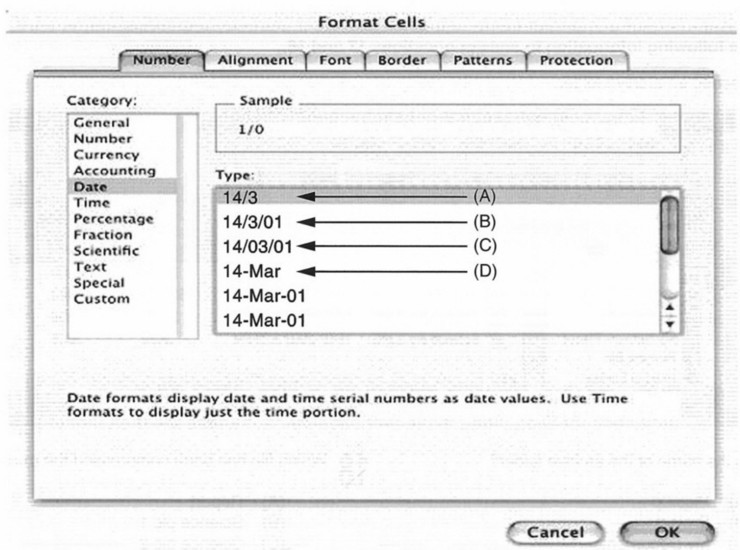
Mr Roberts created this spreadsheet to calculate the percentages of Year 8 students studying elective languages.



	A	B	C
1	Current info as at:	19/02/05	
2			
3	Elective Language	Number of students	Percentage
4	French	16	18.0%
5	German	9	10.1%
6	Italian	12	13.5%
7	Japanese	18	20.2%
8	Indonesian	15	16.9%
9	Korean	8	9.0%
10	None	11	12.4%
11			
12	Total	89	100.0%

19 Cell B1 is formatted as a Date.

Which of the following shows the type of formatting for this cell?



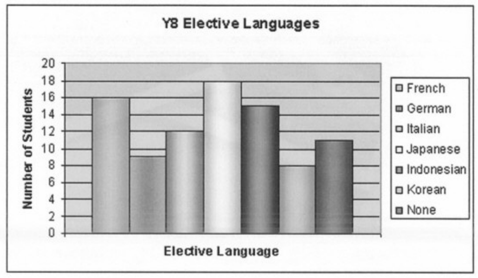
20 Mr Roberts used the Percentage format for column C. He entered a formula into cell C4 and then used Fill Down to complete the column C values.

What formula did he enter into cell C4?

(A) =B4/B12
(B) =$B4/B12
(C) =B4/B12
(D) =B4/$B12

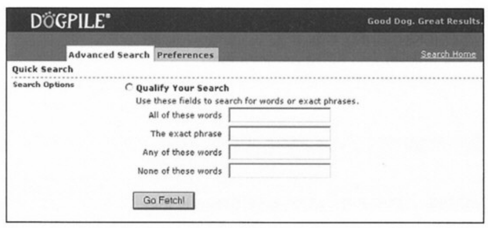
21 What data range did he select to create this graph?

(A) C3:C10
(B) A3:C10
(C) B3:B10
(D) A3:B10

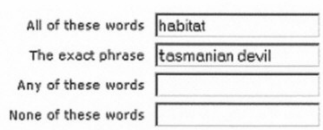


INTERNET SKILLS — SEARCH ENGINES

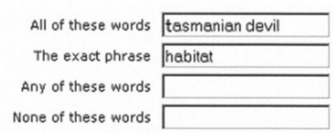
22 Kim is using this search engine to search for information about Tasmanian Devils and their habitat. The words used for the search would be *tasmanian devil* and *habitat*.



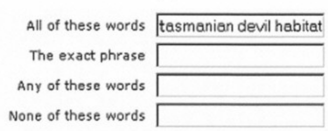
Which of the following is the **least** efficient strategy for finding this information?



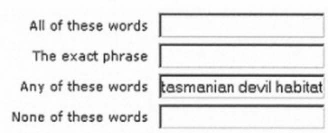
(A)



(B)



(C)



(D)

Use the following information to answer questions 23 and 24.

John wants to send 20 high resolution holiday pictures to his cousin in New Zealand. He has saved his pictures as JPEG files.

23 Which of the following connections is the fastest way to transfer these files?

(A) satellite and modem combination at 48 Kbps upload and 512 Kbps download
(B) ADSL broadband at 128 Kbps upload and 512 Kbps download
(C) mobile phone at 10 Kbps upload and 33 Kbps download
(D) dialup at 48 Kbps upload and 56 Kbps download

24 Which one of the following statements is true about JPEG files?

(A) They upload quickly although some image quality is lost.
(B) They retain perfect image quality but support only 256 colours.
(C) They are a compressed file format which is not supported by all platforms.
(D) They are not supported by all web browsers and the level of compression cannot be varied.

Use the following information to answer questions 25 and 26.

Tran has created this database of roller coasters.

Coasters : Table

ID	Roller Coaster	Amusement Par	City	Country	Safety Check
1	Dizzy Dipper	Theme Park	Sydney	Australia	☑
2	Thunderstorm	Dream Park	Melbourne	Australia	☐
3	Jazz Group	Jazzland	Adelaide	Australia	☑
4	Underground	Fun Park	Sentosa	Singapore	☑
5	Speed Flash	Jerudong Park	Bandar Seri	Brunei	☑
6	Splash	Sea Park	Surfers Paradise	Australia	☐
7	Twister	Sea Park	Surfers Paradise	Australia	☐
8	Tornado	Movie Park	Sentosa	Singapore	☐
AutoNumber)					

Record: 8 of 8

He then produced the following Safety Report from his database.

Safety

Safety

Roller Coaster	Amusement Park	City	Country
Dizzy Dipper	Theme Park	Sydney	Australia
Jazz Group	Jazzland	Adelaide	Australia
Underground	Fun Park	Sentosa	Singapore
Speed Flash	Jerudong Park	Bandar Seri	Brunei

Page: 1

25 Which of the following SQL statements was used to produce the report?

(A) SELECT Coasters.[Roller Coaster], Coasters.[Amusement Park], Coasters.City, Coasters.Country
FROM Coasters
WHERE Country=True;

(B) SELECT Coasters.[Roller Coaster], Coasters. Coasters.City, [Amusement Park], Coasters.Country
FROM Coasters
WHERE Coasters.[Safety Check]=True;

(C) SELECT Coasters.[Roller Coaster], Coasters.[Amusement Park], Coasters.City, Coasters.Country
FROM Coasters
WHERE Coasters.[Safety Check]=True;

(D) SELECT.[Roller Coaster]Coasters, Coasters.[Amusement Park], Coasters.City, Coasters.Country
FROM Coasters
WHERE Coasters.[Safety Check]=True;

26 Tran wanted to change “Sea Park”, each time it occurs, to “Sea World”. He wrote an SQL statement to do this. One word in his statement is covered.

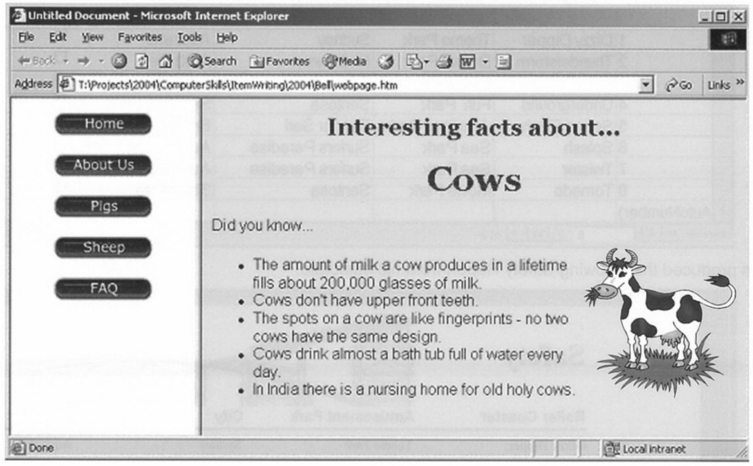
UPDATE Coasters SET ______ [Amusement Park] = “Sea World”
WHERE Coasters.[Amusement Park] = “Sea Park”

What is the missing word?

(A) Table
(B) Record
(C) Change
(D) Coasters

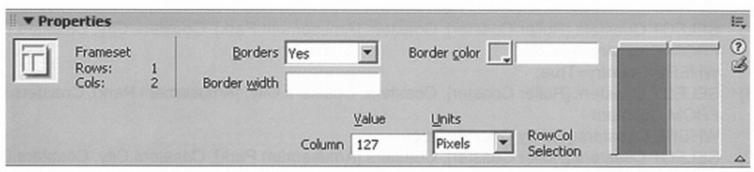
Use the following information to answer questions 27 to 30.

Rajiv made this web page in a program called Dreamweaver and previewed it in Internet Explorer.



27 Rajiv's web page displays two frames. He decided the web page would look better if the border between the frames could not be seen.

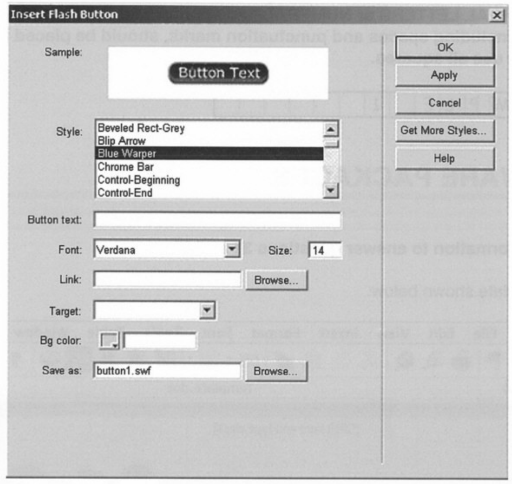
This is the Properties dialogue box.



Which property **CANNOT** be used to make the line between the frames invisible?

(A) Borders
(B) Border width
(C) Border color
(D) Column Value

28 Rajiv used this dialogue box to insert a button into the web page.



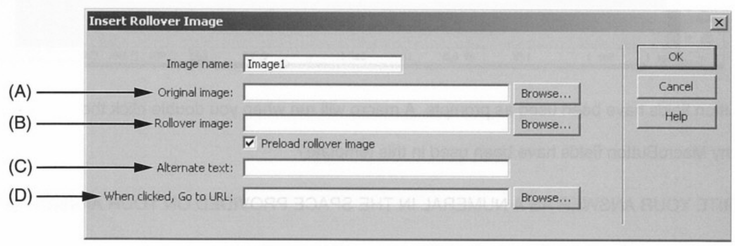
If he wants to display the word OPEN on the button and name the button DOCUMENT, he should type

(A) OPEN in the "Link:" field and DOCUMENT in the "Save as:" field.
(B) OPEN in the "Button text:" field and DOCUMENT in the "Save as:" field.
(C) OPEN in the "Target:" field and DOCUMENT in the "Button text:" field.
(D) OPEN in the "Save as:" field and DOCUMENT in the "Button text:" field.

29 Rajiv decided to insert a rollover image in his web page. A rollover image is an image that changes to another image as the mouse moves over it, and then changes back when the mouse leaves.

This is the Insert Rollover Image dialogue box.

Which option would Rajiv use to make the rollover image a link?



30 What is the benefit of selecting "Preload rollover image"?

(A) The web page will take less time to load.
(B) The image will take less time to change when rolled over.
(C) Both images will be visible at the same time.
(D) The image will appear first when the web page is loaded.

Short-Answer Section

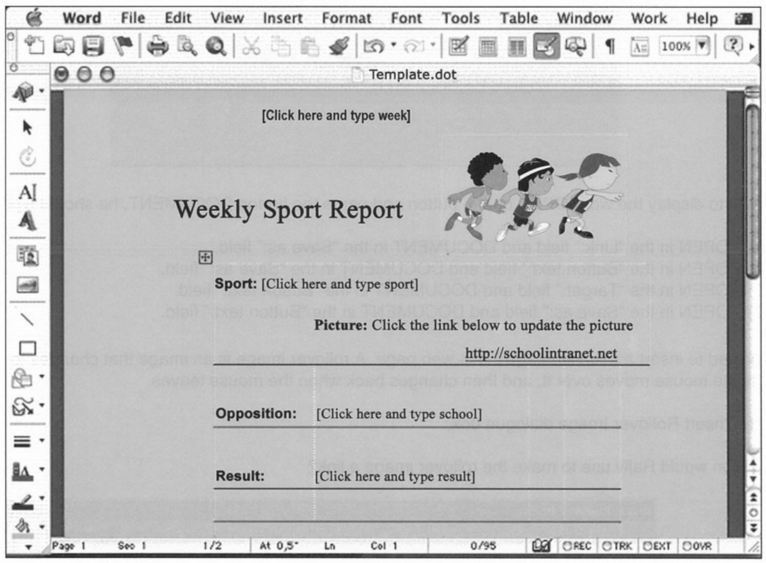
In this section you must write your answers in the spaces provided on your ANSWER SHEET. Write neatly because your answers are marked by a machine that relies on handwriting being clear. Use CAPITAL LETTERS or NUMERALS as appropriate. Start at the left-hand square. Only one character, including spaces and punctuation marks, should be placed in each square. You may not need to use all squares.

Example: | E | X | A | M | P | L | E | | 1 | | | | | | |

USING SOFTWARE PACKAGES

Use the following information to answer questions 31 and 32.

Lucy created the template shown below.



31 MacroButton fields have been used as prompts. A macro will run when you double-click the MacroButton field.

How many MacroButton fields have been used in this template?

WRITE YOUR ANSWER AS A NUMERAL IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

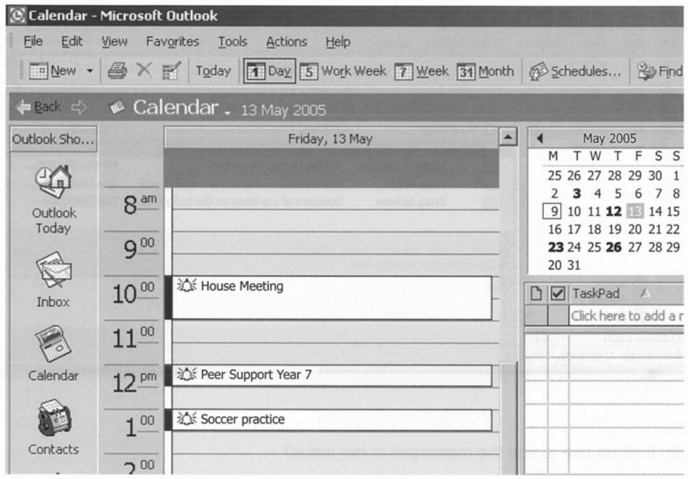
32 Lucy wants to create a completely different template.

What command under the File Menu should she choose?

WRITE YOUR ANSWER IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

Use the following information to answer questions 33 and 34.

This screenshot shows Glenn's Outlook calendar.



33 On Monday 9 May, Glenn checked his calendar to see what appointments he had for Friday 13 May.

For how many **other** days in May has Glenn scheduled appointments using this calendar?

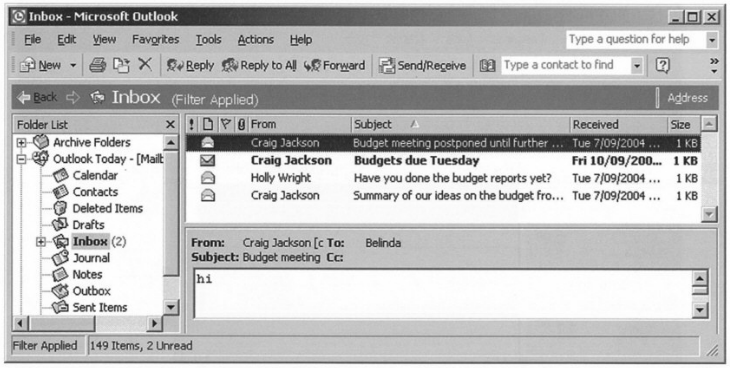
WRITE YOUR ANSWER IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

34 At what time is the House Meeting scheduled to **finish**?

WRITE YOUR ANSWER IN THE FORMAT HH:MM IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

Use the following information to answer questions 35 to 37.

This is a screenshot of Belinda's Inbox.



35 Which field did Belinda use to sort the messages in her Inbox?

WRITE YOUR ANSWER IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

36 Belinda has applied a filter to the Inbox.

How many items in Belinda's Inbox are currently hidden from sight?

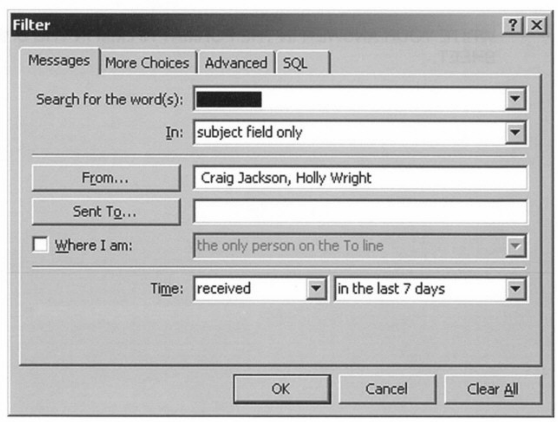
WRITE YOUR ANSWER AS A NUMERAL IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

37 This is the filter Belinda applied to the Inbox.

The word in the first box has been blacked out.

What word did Belinda type in the first box?

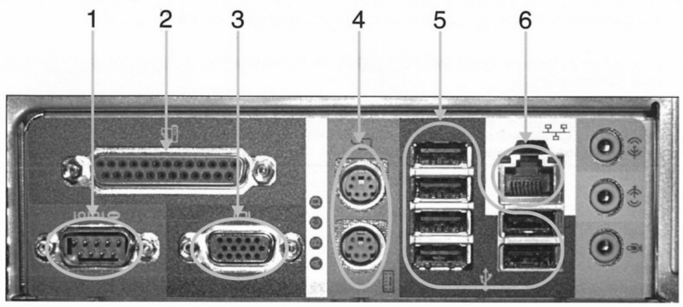
WRITE YOUR ANSWER IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.



USING COMPUTER HARDWARE

Use the following information to answer questions 38 to 40.

The photograph shows ports on the rear panel of a computer. Two ports of the same type are grouped together and labelled **4**. Another six ports are grouped together and labelled **5**.

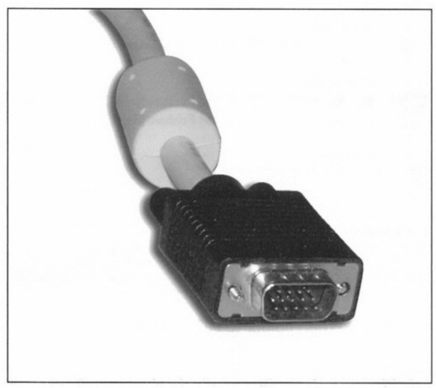


38 The mouse cable plugs into one of the ports labelled 4.

What cable plugs into the other port of this type?

WRITE YOUR ANSWER IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

39 Into which port does this cable plug?



WRITE YOUR ANSWER AS A NUMERAL IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

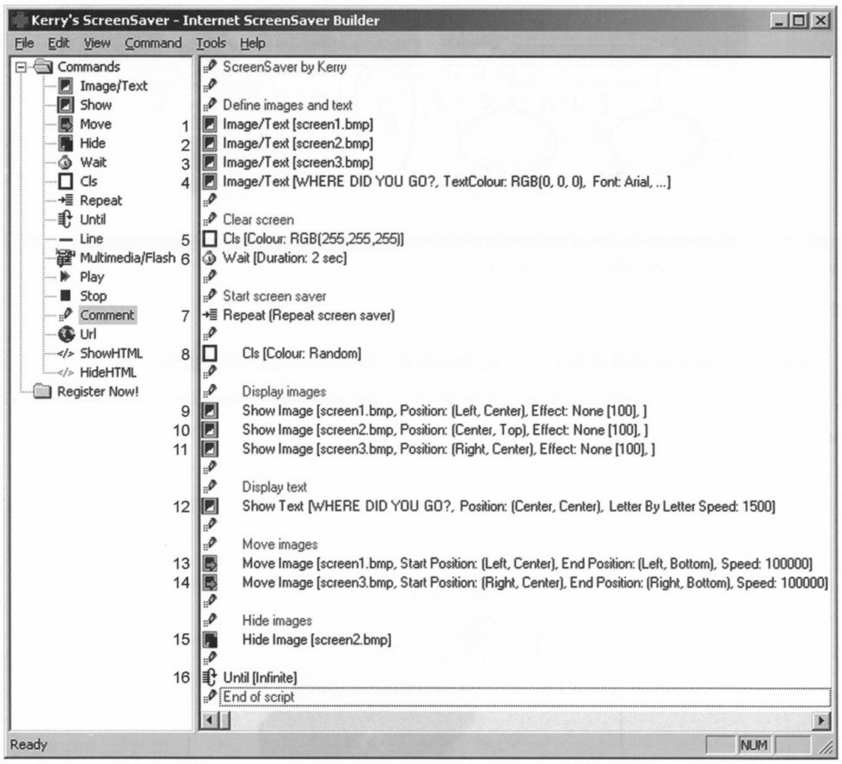
40 What is the name given to the type of cable that plugs into the ports labelled **5**?

WRITE YOUR ANSWER IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

Use the following information to answer questions 41 to 45.

Kerry has used a program to build a screen saver. The script in the right side of the window runs the screen saver and specifies what the screen saver will do and what it will look like. To create each line of script, Kerry clicked on a command from the left side of the window. A dialogue box then appeared and Kerry selected the options for each command. The program then automatically generated the line of script.

The lines of script have been numbered from **1** to **16** for your convenience. <u>Each line of green text is a comment only and is not part of the script.</u>



41 Line 5 clears the screen and sets the screen colour to RGB[255,255,255].

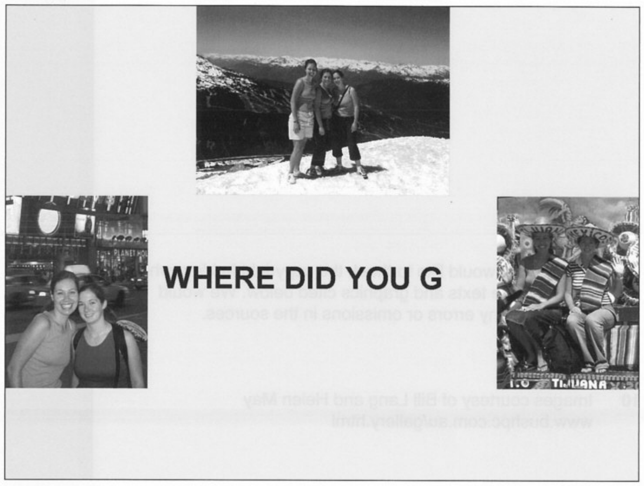
What colour does this represent?

WRITE YOUR ANSWER IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

42 How many images (not including text) are seen on screen immediately before Line 16 is carried out?

WRITE YOUR ANSWER AS A NUMERAL IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

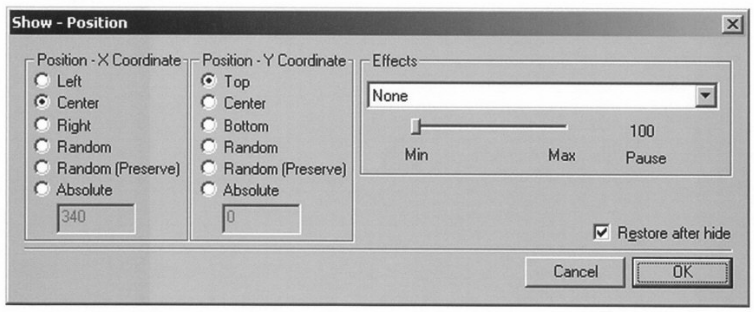
43 Kerry previewed the screen saver and took a screen shot.



Which line of script is being carried out in the screen shot?

WRITE A NUMBER BETWEEN 1 AND 16 IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

44 This is the dialogue box for one of the objects in the screen saver.



What is the file name of this object?

WRITE YOUR ANSWER IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

45 Kerry wants to insert a line of script to make the text "WHERE DID YOU GO?" disappear from the screen.

What command will make the text "WHERE DID YOU GO?" disappear leaving the pictures on screen?

WRITE YOUR ANSWER IN THE SPACE PROVIDED ON YOUR ANSWER SHEET.

ACKNOWLEDGEMENT

Educational Assessment Australia would like to thank the copyright holders who have granted permission to use the texts and graphics cited below. We would appreciate information regarding any errors or omissions in the sources.

SOURCES

Pages 4, 6 and 10 Images courtesy of Bill Lang and Helen May
www.bushpc.com.au/gallery.html

APPENDIX 2

ENNIS-WEIR CRITICAL THINKING ESSAY TEST

Critical Thinking

Introduction

During the last few lessons you have been shown how to use the Reason!Able® software package. Reason!Able® helps you to construct an argument, develop your critical thinking skills and introduces you to logic.

In this assignment you will be able to demonstrate your ability to use Reason!Able® and practise critical thinking.

Task

The attached file contains a letter written to the editor of a newspaper. Your task is to:

1 Read the letter and construct a response using the Reason!Able® software package.

The *main conclusion* in Reason!Able® should be written as a single statement that summarises the purpose of the letter. Your response to the letter should address each of the eight arguments made in the letter. You may support, or oppose, the arguments in the letter. **Remember to evaluate your responses.** Your evaluation of each argument, and the overall letter will be shown by different shades of red and green.

Spend about ten minutes reading the letter and use the rest of the lesson to construct your response. You should hand in your work by the end of the lesson.

The Moorburg Letter

Dear Editor
Overnight parking on all streets in Moorburg should be eliminated. To achieve this goal, parking should be banned between 2 a.m. and 6 a.m. There are a number of reasons why any intelligent person would agree.

1 For one thing, to park overnight is to have a garage in the street. It is illegal for anyone to have a garage in the street. Clearly, then, it should be against the law to park overnight in the streets.

2 Three important streets are very narrow. With cars parked on the streets there really isn't room for the heavy traffic that passes over them in the afternoon peak hour. When driving home in peak hour traffic after work, it takes me thirty-five minutes to make a trip that takes ten minutes at other times. If there were no cars parked on the side of the street then there would be more room for this traffic.

3 Traffic on some streets is also bad in the morning when factory workers are on their way to the 6 a.m. shift. If there were no cars parked on these streets between 2 a.m. and 6 a.m. then there would be more room for this traffic.

4 Furthermore, there can be no doubt that, in general, overnight parking on the streets is undesirable. It is definitely bad and should be opposed.

5 If parking is banned from 2 a.m. to 6 a.m. then accidents between parked and moving vehicles will be nearly eliminated during this period. All intelligent citizens would regard the near elimination of accidents as highly desirable. So, we should be in favour of banning parking from 2 a.m. to 6 a.m.

6 Last month the Chief of Police ran an experiment which proves that parking should be banned from 2 a.m. to 6 a.m. On one of the busiest streets he placed experimental signs for one day. The signs banned parking from 2 a.m. to 6 a.m. During the four hour period there was not one accident on that street. Everyone knows, of course, that there were over 400 accidents during the past year.

7 The opponents of my suggestions have said that conditions are safe enough now. Conditions are not safe if there's even the slightest possible chance for an accident. That's what "safe" means. So, conditions are not safe the way they are now.

8 Finally, let me point out that the Director of National Traffic Safety Council as strongly recommended that overnight street parking be banned on busy streets in cities the size of Moorburg. The National Association of Police Chiefs has made the same recommendation. Both suggest that banning parking from 2 a.m. to 6 a.m. is the best way to prevent overnight parking.

Sincerely,

Robert R. Raywift

APPENDIX 3

SCIENTIFIC CREATIVITY STRUCTURE MODEL

Reproduced with the permission of Professor Philip Adey, King's College, London

Creativity Test

Welcome to our Creativity Test!

Today we would like you to demonstrate a very important ability - scientific creativity. Your creativity will be measured in three ways – the number of different solutions you find; the different types of solutions you find; and how different your solutions are to everybody else's.

You have 7 different tasks. Each task has many solutions. Try to explore as many new ideas and solutions as you can and think of things that no one else in the class will think of.

You should spend about 7 minutes on each task. At the end of 7 minutes, stop your current task and move on to the next task. If you finish early, see if you can add any more solutions to earlier tasks.

If you have questions about the tasks, please raise your hand and ask the examiner.

Have fun!

1 Write down as many as possible scientific uses as you can for a piece of glass.

For example: *make a test tube*

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________
11. ____________________
12. ____________________
13. ____________________
14. ____________________
15. ____________________
16. ____________________
17. ____________________
18. ____________________

19. ____

20. ____

21. ____

22. ____

23. ____

24. ____

25. ____

26. ____

27. ____

28. ____

29. ____

30. ____

31. ____

32. ____

33. ____

34. ____

35. ____

36. ____

37. ____

If you want to add any more answers please ask for extra paper

2 If you could take a spaceship to travel in outer space to another planet, what scientific questions do you want to research? List as many as you can.

For example: *Are there any living things on the planet?*

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________
11. ______________________________
12. ______________________________
13. ______________________________
14. ______________________________
15. ______________________________
16. ______________________________
17. ______________________________
18. ______________________________

19.____

20.____

21.____

22.____

23.____

24.____

25.____

26.____

27.____

28.____

29.____

30.____

31.____

32.____

33.____

34.____

35.____

36.____

37.____

If you want to add any more answers please ask for extra paper

3 Think up as many possible improvements as you can to a regular bicycle, making it more interesting, more useful or more beautiful.

For example: *make the tyres reflective, so they can be seen in the dark*

1. ____

2. ____

3. ____

4. ____

5. ____

6. ____

7. ____

8. ____

9. ____

10. ____

11. ____

12. ____

13. ____

14. ____

15. ____

16. ____

17. ____

18. ____

19. ____

20. ____

21. ____

22. ____

23. ____

24. ____

25. ____

26. ____

27. ____

28. ____

29. ____

30. ____

31. ____

32. ____

33. ____

34. ____

35. ____

36. ____

37. ____

If you want to add any more answers please ask for extra paper

4 Suppose there was no gravity - describe what the world would be like.

For example: *human beings would float*

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

7. ______________________________

8. ______________________________

9. ______________________________

10. ______________________________

11. ______________________________

12. ______________________________

13.

14.

15.

16.

17.

18.

19.

20.

21.

22.

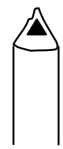
23.

24.

If you want to add any more answers please ask for extra paper

5 How many objects you can make from each pair of lines below? The lines should be the main part of whatever you make. Add titles for each of your products.

For example:



Pencil

If you want to add any more answers please ask for extra paper

6 Imagine that you have been given two types of table napkins. How can you test which is better?

Write down as many possible ways as you can, including the instruments and methods.

If you want to add any more answers please ask for extra paper

7 Design an apple picking machine. Draw a picture and point out the name and function of each part.

APPENDIX 4

COMPUTER LABORATORY ENVIRONMENT INVENTORY; ATTITUDES TOWARDS COMPUTERS AND COMPUTER CLASSES

Notebook Computer Questionnaire

This survey contains a number of statements about notebook computers and your thoughts about their use. For each statement you are asked to indicate if you agree with the statement. You can choose between 'Strongly Disagree', 'Disagree', 'Not Sure', 'Agree' or 'Strongly Agree' by clicking the appropriate button.

Some statements having similar wording to others, but they all differ slightly. Treat each statement individually – you don't need to 'look back' at your previous responses.

There are 49 statements. Completing the survey should take about 10-15 minutes. You will need use the scroll bar to move through all of the questions.

		Strongly Disagree *(1)*	Disagree *(2)*	Not Sure *(3)*	Agree *(4)*	Strongly Agree *(5)*
1	I get on well with students in classes that use notebook computers.	☐	☐	☐	☐	☐
2	My notebook computer work and other class work are not related.	☐	☐	☐	☐	☐
3	There is opportunity for me to follow my own computing interests in class.	☐	☐	☐	☐	☐
4	When I make a mistake my notebook computer behaves OK (it doesn't 'crash')	☐	☐	☐	☐	☐

		Strongly Disagree (1)	Disagree (2)	Not Sure (3)	Agree (4)	Strongly Agree (5)
6	My notebook computer software is difficult to use.	☐	☐	☐	☐	☐
7	I feel comfortable when people talk about notebook computers.	☐	☐	☐	☐	☐
8	I don't have time to get to know other students in classes that use notebook computers.	☐	☐	☐	☐	☐
9	Studying about notebook computers is a waste of time.	☐	☐	☐	☐	☐
10	In classes that use notebook computers I have to design my own answers to problems.	☐	☐	☐	☐	☐
11	It's fun to find out how notebook computer systems work.	☐	☐	☐	☐	☐
12	Notebook computer work is not related to the other class work	☐	☐	☐	☐	☐
13	My notebook computer programs run without any problems.	☐	☐	☐	☐	☐
14	I feel at ease when I am around notebook computers.	☐	☐	☐	☐	☐
15	My future career will need a knowledge of notebook computers.	☐	☐	☐	☐	☐
16	Other students help me when we use notebook computers.	☐	☐	☐	☐	☐
17	I enjoy using a notebook computer.	☐	☐	☐	☐	☐
18	When using a notebook computer, other students get different answers than I do for the same problem.	☐	☐	☐	☐	☐
19	Normal class work is linked with notebook computer activities.	☐	☐	☐	☐	☐

		Strongly Disagree *(1)*	Disagree *(2)*	Not Sure *(3)*	Agree *(4)*	Strongly Agree *(5)*
20	Working with a notebook computer makes me very nervous.					
21	My notebook computer is powerful enough to meet my demands.					
22	When I get a job I will not need to use a notebook computer.					
23	I think that working with notebook computers would be fun.					
24	When I use notebook computers in class I get to know students quite well.					
25	When using a notebook computer I am encouraged to do some investigations of my own.					
26	I get a sinking feeling when I think about using a notebook computer.					
27	I use the theory sessions during notebook computer-based activities.					
28	Notebook computers are important for the success of a business.					
29	Programs on my notebook computer let me work well.					
30	Solving problems with a notebook computer doesn't interest me.					
31	I can depend on other students to help me with my notebook computer.					
32	Notebook computers make me feel uncomfortable.					

		Strongly Disagree *(1)*	Disagree *(2)*	Not Sure *(3)*	Agree *(4)*	Strongly Agree *(5)*
33	When I use a notebook computer in class I solve different problems to some other students.					
34	In future, notebook computers will be used more often in school.					
35	Class work completed on my notebook computer is quite different to other class work.					
36	I would like to work with notebook computers.					
37	My notebook computer is in good working condition.					
38	Notebook computers make me feel uneasy and confused.					
39	It takes me a long time to get to know everybody by their first name in classes that use notebook computers.					
40	All students need to learn about notebook computers.					
41	My teacher decides how I should solve problems with my notebook computer.					
42	I enjoy learning on a notebook computer.					
43	Using my notebook computer helps me understand my work.					
44	My notebook computer is able to run all the programs I need to use.					
45	I feel aggressive and hostile towards notebook computers.					

		Strongly Disagree *(1)*	Disagree *(2)*	Not Sure *(3)*	Agree *(4)*	Strongly Agree *(5)*
46	Knowledge about using notebook computers will help me get a job.	○	○	○	○	○
47	When I use a notebook computer I work cooperatively with other students.	○	○	○	○	○
48	Learning about notebook computers is boring.	○	○	○	○	○
49	I decide the best way to solve problems on a notebook computer.	○	○	○	○	○

Submit Reset

APPENDIX 5

QUESTIONNAIRE ON TEACHER INTERACTION

Questionnaire on your Technology Teacher

This questionnaire asks you to describe the behaviour of your teacher.

This is **NOT** a test.

Your opinion is what is wanted.

This questionnaire has 48 sentences about your teacher. For each sentence, click the radio button that corresponds to your response.

For example:

		Never *0*	*1*	*2*	*3*	*Always* *4*
Q	My teacher smiles	☐	☐	☐	☐	☐

Please answer all questions. If you want to change an answer, click on a different radio button.

Thank you for your cooperation.

		Never *0*	*1*	*2*	*3*	*Always* *4*
1	My teacher talks enthusiastically about her/his subject.	☐	☐	☐	☐	☐
2	My teacher trusts me.	☐	☐	☐	☐	☐
3	My teacher seems uncertain.	☐	☐	☐	☐	☐
4	My teacher gets angry unexpectedly.	☐	☐	☐	☐	☐
5	My teacher explains things clearly.	☐	☐	☐	☐	☐
6	If I don't agree with my teacher, I can talk about it.	☐	☐	☐	☐	☐
7	My teacher is hesitant.	☐	☐	☐	☐	☐
8	My teacher gets angry quickly.	☐	☐	☐	☐	☐

		Never *0*	*1*	*2*	*3*	*Always* *4*
9	My teacher holds my attention.					
10	My teacher is willing to explain things again.					
11	My teacher acts as if she/he does not know what to do.					
12	My teacher is too quick to correct me when I break a rule.					
13	My teacher knows everything that goes on in the classroom.					
14	If I have something to say, my teacher will listen.					
15	My teacher lets me boss her/him around.					
16	My teacher is impatient.					
17	My teacher is a good leader.					
18	My teacher realises when I don't understand.					
19	My teacher is not sure what to do when I fool around.					
0	It is easy to pick a fight with my teacher.					
21	My teacher acts confidently.					
22	My teacher is patient.					
23	It's easy to make my teacher appear unsure.					
24	My teacher makes mocking remarks.					

		Never *0*	*1*	*2*	*3*	*Always* *4*
25	My teacher helps me with our work.					
26	I can decide some things in my teacher's class.					
27	My teacher thinks that I cheat.					
28	My teacher is strict.					
29	My teacher is friendly.					
30	I can influence my teacher.					
31	My teacher thinks that I don't know anything.					
32	I have to be silent in my teacher's class.					
33	My teacher is someone I can depend on.					
34	My teacher lets me decide when I will do the work in class.					
35	My teacher puts me down.					
36	My teacher's tests are hard.					
37	My teacher has a sense of humour.					
38	My teacher lets me get away with a lot in class.					
39	My teacher thinks that I can't do things well.					
40	My teacher's standards are very high.					
41	My teacher can take a joke.					

		Never *0*	*1*	*2*	*3*	*Always* *4*
42	My teacher gives me a lot of free time in class.					
43	My teacher seems dissatisfied.					
44	My teacher is severe when marking papers.					
45	My teacher's class is pleasant.					
46	My teacher is lenient.					
47	My teacher is suspicious.					
48	I am afraid of my teacher.					

Submit Reset