The application of a technique for enhancing recall to improve learning in the science classroom

by

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ABSTRACT

There has existed for many years a memory enhancement technique ("memory pegs") that although having dramatic demonstrable success in some individual cases has not been generally applied in education.

The emergence of constructivist epistemology has emphasised the notion that learning occurs as a result of connecting new material with previously learnt concepts. There is, therefore, the implication that effective learning requires some previous knowledge upon which to attach new concepts - and thus realisation of the importance of learning with respect to acquiring factual information as a pre-requisite to learning new processes and/or skills. This issue has focussed my attention on the need to ensure that the more physiological skills of accessing ‘memory’, both for learning and recall, are optimised for maximum learning. Further, there are some indications that the physiological skills of memory access (storage and retrieval) may respond favourably to training and 'exercise'.

This study was designed to find out whether or not a repeated ‘exercise’ using a simple memory enhancement technique would lead to a determinable and statistically significant increase in overall performance in a range of cognitive skills (as indicated by science and mathematics examination results), whether learning such a technique would affect a student’s attitudes towards science, whether there was a relationship between the amount of time spent practicing the technique and the degree of effect, and whether the memory technique did actually improve the ability to recall lists of objects.

Although the analysis of data gathered during the course of this study did support an observation that there was a general increase in achievement in assessments, the improvement in results was not dramatic enough to be significant. No effect on attitudes towards science was evident. The data gathered concerning the amount of practice time proved to be insufficient to determine a trend. Within the limitations of the research, the data showed that the ability to remember a list of objects had been significantly improved, there was no clear evidence of transference of this ability to result in improved examination or assessment results.

ACKNOWLEDGEMENTS

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In particular, my thesis supervisor, Professor David Treagust of Curtin University of Technology, Perth, Australia has assisted in many ways over the years.

I also wish to thank the students of the Hills (then known as South Queensland) International College, of Jimboomba, Queensland, who so willingly took part in this investigation as the test group, and also to those students whose results are used as the control group.

Finally, special thanks to my wife, Robyn, for not nagging about the “to do” list stuck to the side of my computer, which has been largely ignored for a very long time.

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1 INTRODUCTION

1.1 Introduction

This chapter provides an overview of and introduction to the study, looking in general terms at

- the purpose of the study (section 1.2),
- the four research questions investigated by this study (section 1.3),
- the background to the study and research questions (section 1.4),
- the rationale for the study (section 1.5),
- an overview of the methods used in the study (section 1.6),
- the significance of the study and its finding to researchers and teachers (section 1.7), and
- the expected and unexpected limitations of the study (section 1.8).

Each of these aspects is explored further during the body of the thesis.

1.2 Purpose of the Study

There are records in the popular literature of examples of otherwise ordinary people who have trained their memory with various mnemonic and other techniques, and subsequently demonstrated incredible facility in recall of information. Yet these techniques have not generally been taught in schools. Some people have memorised telephone books worth of information, or can memorise sequences of hundreds of random and irrelevant digits in minutes (Buzan & Keene, 1994), yet in our schools many students consistently fail to recall even the most simple and relevant scientific facts and formulae during examinations.

The study was designed to investigate the feasibility and advisability of linking the body of knowledge associated with memory development and enhancement with the established epistemology and pedagogy, specifically to determine whether or not there is sufficient justification for introducing memory training into an educational environment.

While some people have benefited in some ways from learning memory techniques (see Clare, Wilson, Carter, Roth, Hodges (2002), and Buzan and Keene (1994 and 1996)), for example, by being able to recall lists of unrelated objects, or the sequence of decks of cards, or random words or numbers, there has been a lack of study done on whether the practice of such techniques would benefit students undertaking normal studies at school. That is, would learning the ability to recall lists of objects result in an increased ability to recall the basic facts of science and mathematics, and would this lead to an increased performance in other areas of assessment, for example, of complex reasoning and problem solving skills. This study was designed to open up a potentially new area for academic research by addressing this lack.

1.3 The Problem and Research Questions

Since the acquisition of knowledge is fundamental to the demonstration of understanding, this study poses the overall general research question:

> Will the practice of a simple memory training technique enhance student performance on a range of cognitive aspects of science and mathematics examinations (i.e. recall and simple application, and complex reasoning / problem solving), or affect their opinions about science and scientists?

The cognitive skills of recall and simple application, and complex reasoning / problem solving are mentioned since they reflect the way that student achievement is assessed within the science and mathematics curricula of Queensland, Australia, where the study was based. Details may be found in the Queensland Junior and Senior science and mathematics syllabi, specifically those implemented between 1994 and 2004 (e.g Board of Senior Secondary School Studies Senior Chemistry Syllabus 1994).

This researcher has been unable to locate any additional evidence in the science education literature reporting investigations into the use of memory training techniques to improve science academic achievement. Nevertheless several plausible potential effects in the classroom such as learning the symbols of the periodic table from an increased ability to memorise. These were:

- a potential increase in the recall of facts related to classroom work, as would be indicated by an increase in scores on the assessment of the recall and simple application sections of science and mathematics subject tests,
- a potential increase in the ability to solve more complex problems, as would be indicated by the increase in the scores on the assessment of complex reasoning process sections of science and mathematics subject tests
- a potential change in attitude towards science and mathematics, as may be measured with a suitable assessment instrument in pre- and post- testing of the test and control groups.

Additionally, there were identified several factors affecting the nature of the participants in the study which may have resulted in a variation in the effectiveness of the memory training. These were:

- age of the participants in the study,
- sex of the participants in the study,
- nationality of the participants in the study,
- native language of the participants in the study,
- prior academic achievements of the participants in the study,
- prior attitudes towards science and mathematics of the participants in the study.

In assessing the impact of any memory training technique upon academic achievement, there also arises the problem of, and the potential for, many other variables affecting that performance. Many of these variables have been identified in the research literature and investigated in a large number of trials. These are discussed further later.

From a consideration of the above, four research questions were posed.

1. Does the learning of a memory enhancement technique lead to a significant increase in a student's results in assessments in science and mathematics in either of the two facets of assessment, recall and complex reasoning?
2. Does the learning of a memory enhancement technique lead to a significant change in attitude towards science?
3. Does the learning of a memory enhancement technique lead to a significant improvement in the ability to recall lists of unrelated objects?
4. Does the amount of time spent practicing a memory enhancement technique improve performance on a test of recall?

1.4 Background to the Problem

In 1983, this researcher completed a personal development course ("Alpha Dynamic Mind Dynamics") that contained, as a relatively small component of the overall course, a memory training technique. The presenters of that course made claims that repeated practice of this technique would lead to an improvement in overall memory performance. These claims appear to have been made based upon hearsay gathered from a number of persons over a long period of time. Indeed, some purported success stories were related as part of the training. As this researcher subsequently became a workshop leader and taught the technique to many adults, I also received some anecdotal reports from many participants tending to support these claims.

In 1984, when this researcher commenced teaching duties, and over subsequent years as a teacher, I have become increasingly frustrated that there are a large number of students coming into high school classes who apparently lack basic learning skills. By this I do not mean the Attention Deficit Disorder or Attention Deficit Hyperactivity Disorder or other medically or educationally identified learning difficulties, but a more basic skill of actually causing a memory to form in their brains, and the ability to retrieve that memory later during test conditions. It seems to me that although a certain proportion of students stumble across some technique that works, use it effectively, and do very well, a certain proportion never figure out how to learn, and do poorly, and the rest achieve a somewhat hit-and-miss approach that places them in the middle rank academically.

Knowing that I learned the ability to memorise lists of 40 to 50 unrelated objects and recall them word perfect for weeks later, it remains a source of irritation that students typically cannot remember 20 facts for an examination.

This situation has been of concern for my entire teaching career, and I viewed this research project as an opportunity to further investigate and potentially discover a solution to his problem.

1.5 Rationale for the Study

As stated earlier, although there are many examples of persons, who through applying easily learnt and practiced tricks or techniques, have demonstrated exceptional ability to recall large quantities of material, there seems to be little research about the application of these techniques to the educational process as occurs in schools. Many students fail to learn the material presented to them, to the point that very few students demonstrate an ability to learn *all* of the material. Compare, as a hypothetical example, the competitors in the world memory championships, who manage to memorise the order of a deck of 52 cards in a matter of a minute (Buzan & Keene, 1994), and recall this order with 100% accuracy, to the ‘below average’ student, who fails to recall even half of the 20 facts assessed in a science test, having been given a term in which to learn them.

It has been a concern to the author for many years that despite efforts to provide excellent teaching strategies, utilise full and extensive resources, design interesting lessons, and create student-centred learning experiences, a significant proportion of students still fail to recall basic facts, let alone apply them to complex or novel situations. This is further aggravated by the common practice in Queensland of providing students with a list of the facts that they must recall at the start of the teaching unit, and basing the assessment test directly on that list of facts. Therefore students have had 8 to 10 weeks in which to learn 20 simply stated items (for example, “velocity is the displacement travelled per time interval”) and then to recall them in a test (for example, “What is velocity?”). This has led the author to question the source of the problem and to believe that perhaps the difficulty lies in the student's ability to effectively memorise, and then to retrieve the memory – that is, to actually learn.

The bulk of literature relating to the improvement of the educational process typically focuses on improving *teaching* rather than directly addressing why a student does not *learn*. Thus, I recall having completed programmes such as "Excellence in Teaching" early in my teaching career that presented a wide and diverse range of micro-teaching skills aimed at ensuring that students received the information presented by the teacher, and yet, even when these techniques were applied correctly, there were students in the class who still did not demonstrate the ability to learn anything from the teacher.

This study attempts to investigate another avenue for research, that of directly teaching students how to learn within an educational setting, and specifically in teaching students how to memorise and recall information, in the belief that the skills of memorising and recall are fundamental to the educational process, and that there should be observable and testable improvements in educational assessment results following the mastery and use of these memory skills.

1.6 Overview of Methods Used in the Study

The study used a group of school-aged volunteers who were taught a simple yet considered to be effective technique for memorising lists of unrelated objects. The assessment results of this test group were recorded for nine months prior to and subsequent to the training sessions, and compared to a control group of students from the same classes who did not undergo such training. These data were used to investigate the first research question, whether such training had a significant effect on academic achievement.

In order to investigate whether the training program affected the affective aspects of science, that is, the opinions held by the students, the test group and some of the control group were administered the Test of Science Related Attitudes (TOSRA), (Fraser, 1981) prior to and some months following the intervention. This investigation constituted an attempt to answer the second research question.

In order to validate or disprove the memory technique itself, as the third research question, at the end of a nine-month period the test group attempted to recall a list of objects that they had memorised nine months earlier. A small group of untrained persons attempted to memorise the list for one week as a comparison group.

The fourth research question focussed on whether the amount of time spent practicing the technique had a significant impact on the effectiveness of the training program. The volunteers recorded the amount of time that they spent practicing the technique, and these data are analysed also.

Data for the aforementioned investigations were gathered into a specially written database program from which various tables of means, standard deviations, and Student's t-score analyses were generated for inclusion in this thesis.

1.7 Significance of the Study

The memory technique tested in this study potentially has application in the classroom by all students. The memory technique, when used successfully, provides a practical demonstration of the effectiveness of the students' memory, which might reduce the lack of confidence of some students, enabling them to achieve better through an increased level of confidence in their ability.

The technique used for this study emphasises the importance of sensory rich experience in memorising. This has implications that are important for teachers to grasp. Teachers who facilitate sensory rich learning experiences in a manner similar to that used in the memory training technique may find that students have an increased recall of subject matter, leading to increased educational outcomes.

The concept of teaching students how to memorise can potentially influence the developers of state or federal curricula in that they may choose to write memory training techniques into the curricula as a mandatory process in early primary, or a remedial process in later stages of schooling.

1.8 Limitations

There are two major limitations inherent in this study.

Firstly, the sample size was limited by the size of the school chosen as the centre of the study. Due to my teaching commitments, and the location of home and work, I was unable to gain sufficient time or access to permit the involvement of students outside my own school. Because the data being gathered spanned a time period of almost two years, and the population of the school was fluctuating, and because the nature of the memory technique was such that non-English speakers would have been disadvantaged (see “Sampling Procedures – restrictions” later) the available pool of participants was only 59 students, of which only 20 volunteered to be part of the test group. (The other 39 students were used as a control group.) On such a small sample, stringent and valid comparisons are problematical.

Secondly, because the study is comparing the achievement as measured by the participant’s results on normal school assessment, acknowledgement must be made that there are a large number of factors, outside of the technique taught in the intervention process, which may affect individual student’s performance. It is innately improbable that all variables affecting student performance on school assessment can be controlled to any extent, resulting in data that inherently cannot be absolutely determined to be a result of the intervention.

The combination of these two factors means that the results of this study should be interpreted as providing indicative general trends rather than an objective ‘proof’ or otherwise of the use of the memory enhancement technique in science or mathematics classrooms.

1.9 Overview of the Thesis

The second chapter contains a review of the literature related to the memory enhancement technique used in this study as well as literature support for the hypothesis that improving memory through training is achievable, and why improved recall ability should lead to improved performance in higher order cognitive functions such as complex reasoning.

The third chapter reports in detail on the research design, the target population, sampling procedures, some details of the intervention, and discussion of the data source and the analysis of the data, as well as identifying the reliability and validity measures used in the data analysis.

The fourth chapter discusses, in detail, the data that was collected, and the results of the analyses conducted upon the data.

The fifth chapter summarises the conclusions made on the research questions, outlines the limitations of the study, and makes recommendations to both researchers and teachers.

The appendices contain more detail about the technique used and record various results for the test and control groups.

2 LITERATURE REVIEW

2.1 Overview of the Chapter

This chapter reviews literature within four sections.

- Nature of learning, memory and understanding (section 2.2) presents literature about the nature of learning, memory, and understanding, indicating that there is support for the proposal that an increase in memory efficacy should result in greater understanding.

- Teaching how to learn (section 2.3) presents literature that indicates that, although there are numerous articles discussing and investigating the art of teaching, there are fewer that directly address how to learn.

- Barriers to Effective learning (section 2.4) summarises the considerable educational literature outlining barriers to effective learning, and proposing techniques to alleviate those barriers, and provides support for the idea that learning memory enhancement techniques may improve achievement by removing or reducing the effect of some of these barriers to effective learning.

- Literature support for memory enhancement techniques (section 2.5) summarises the articles and reports in the literature supporting the idea that memory training techniques can enhance cognitive skills.

2.2 Nature of Learning, Memory and Understanding

2.2.1 Memory Formation

In Phaedrus (275, tracts A-B, and the Seventh letter, as quoted in Bowen, 1971), Plato spoke against formal lectures and making records of them. He asserted that note taking is simply a form of mnemonic activity that gives only a semblance of knowledge. He did not promote manuals of instruction and denied that notes were an aid to memory *because truth, once grasped, will never be forgotten*. This latter assertion is worthy of investigation, as it implies a permanency of memory at odds with the observed fact of student failure in schools. Do elephants (or students) ever forget, or is the problem that they never learn (*grasp the truth)* in the first place? The existence of 'forgetting' means that, ultimately, education is limited in scope and possibility, whereas if the problem is in not learning properly in the first place, then a focus on better *learning skills* is not only desirable but essential. In order to answer the question of whether we forget, or fail to learn, we must look at what memory is.

As a starting point, Howard (1988) outlines a theory on how memory works in terms of schemata which he defines as mental representations which facilitate sorting things into categories - thus a schemata will have slots for characteristics, each characteristic may be different, but the set of characteristics is common. Thus, a schemata for 'animal' might have slots for number of legs, type of fur, position of ears, etc, with each category of animal having different characteristics recorded in each slot. Similar animals may be categorised as the same as another but with a noted variation in some characteristic. This, the schemata 'dog' has some common traits with 'cat', for example, four legs, fur, and a tail, and some differences, for example friendliness, trainability, and milk-drinking. The concept of schema, or some form of holistic representation, will be further developed later.

From a more physiological perspective, Carter (1998) makes the following statements about memory and memory formation:

- Memory is a pattern of neurones in the brain firing simultaneously, triggering the firing of related patterns (p. 159). The mentally held ‘question’ of “my name is …?” somehow triggers the firing of a pattern of neurones that brings forth the answer.
- Establishing a memory is accomplished by the repeated firing of neurones in a particular pattern or sequence of patterns, leading to increased probability that the firing of any part of the pattern will trigger the firing of the whole pattern (i.e. remembering from a stimulus, or remembering the whole when reminded of a part) (p. 159-160). There is an implication here that to remember something, we must first remember something about the something – for example, to recall a person’s name requires some clue as to the person’s identity, maybe hair style or colour, or the relationship they have to you. Compare these two questions: “What is the name of the person I am talking about?” and “What is the name of your mother?” The latter question is easily answered; the former is impossible, although guesses may be made – a certain minimum amount of information is necessary to cue the solution.
- Neurone patterns can overlap, and new patterns that make substantial use of existing patterns will be created more easily than those requiring entirely new structures (p. 161). This is a physiological perspective of the constructivist principle of new learning building upon prior learning – that is, once you have learned what a ‘dog’ is, it is easier to learn what a ‘cat’ is, because of the shared patterns (both have four legs, fur, etc) so all one need do is learn the few differences, whereas learning what a bicycle is takes more effort because there are no common characteristics with ‘dog’.
- Emotional excitement (fear, love, laughter) is brought about by a surge of excitatory neurotransmitters that will also increase the intensity of a perception, as well as facilitating the formation of memory (p. 164). Emotion, and particularly strong emotion, appears to catalyse the formation of memory.

These views together indicate that there is some form of physiological storage mechanism, which presumably operates efficiently. That is, memories are often overlaid, using bits of other memories or previously learned material. This information fits with the constructivist idea that new learning is constructed onto older known things (as outlined, for example, by Noddings (1990), Cobb et al (1992), Solomon (1992), Ernest (1995), and Taylor (1996)). Now, the process of recall can be considered as the retrieval of these patterns, achieved by stimulating part of the overall pattern, and having the entire pattern ‘firing’. Also implicit in this understanding is a justification for believing that repeated practice (i.e., repeated firing in a particular sequence) can lead to more readily accessed patterns – that is, repeated experience of material leads to better recall. This much seems intuitively acceptable to me as a teacher, as it predicates the effectiveness and necessity for homework, revision, and study.

Carter (1998, p. 170) also discusses several instances of how memories might not be immediately retrievable, but interestingly (throughout the book) mainly discusses the loss of memory primarily in terms of disease or injury, or of failure to move memory from short-term to long-term storage. The implication is that Carter considers that perhaps the formation of neural pathways (as in long-term memory) is permanent, which also seems intuitively possible if we look at the evolutionary development of memory. It hardly seems likely that ‘forgetting’ about an experience that almost resulted in death because of wrong choices made would be conducive to future survival in similar experiences and choices. If this is so, then how does one explain that it is difficult to remember the colour of the candles on your fifth birthday cake (or even whether you had a cake?)?

There is a clue in Carter's third point, above - it seems that the patterns of neurones overlap to permit maximum efficiency, and loss of recall might therefore be more a problem of overlaid confusion rather than of 'fading' patterns. An analogy is presented in Figure 1. In the first diagram of figure 1, the memory represented by the square is easy to find, thus the memory it represents will be easy to recall. In the second diagram, the square is difficult to locate because it is overlaid with many other shapes. The memory that it represents may be difficult to recall, not because the memory is any less distinct than in the diagram on the left, but because of the confusion caused by it being ‘lost’ in a jumble of other memories. Hence your difficulty in remembering the colour of the candles on your fifth birthday cake may be that the memory of it is lost amongst many other memories of cakes and candles (your’s and other peoples’), not necessarily that the memory is ‘lost’ or ‘forgotten’.

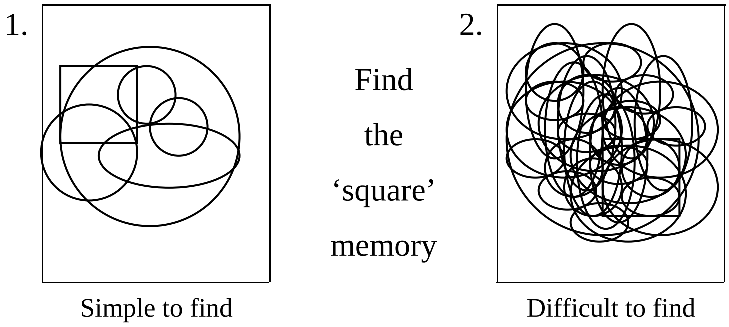

Figure 1: Analogy for why we do not recall even though we do not forget

If there were truth in this conjecture, then enhancing recall should be facilitated by either:

- creating a more memorable experience or more deeply embedded memory (i.e., in the Figure 1 analogy, making the square in the second diagram twice as thick as the other shapes - see Figure 2, diagram 1), or
- by otherwise labelling or tagging the memory to make its recall easier (i.e., by attaching an arrow to it, or by pointing out that the corner of the square is the third line in from the lower right- see Figure 2 diagram 2).

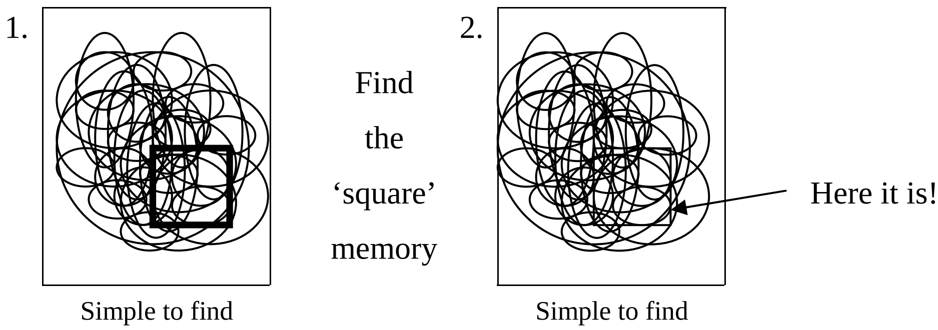

Figure 2: Two analogies for assisting recall

The first approach in the analogies presented in Figure 2 is to deeply impress this aspect of the memory, to make it stand out more than the other memories. This, from a behaviourist viewpoint, makes sense - in our evolutionary past, there is a survival and efficiency benefit in deeply impressing emotionally traumatic events (e.g., almost being eaten) while down-playing mundane events (e.g., seeing a tree). This same thinking could be used to explain why we can easily recall traumatic events at long past times in our lives (what we were doing when we heard about a tragedy which affected us) while not recalling the colour of the candles on the birthday cake we had a year or so ago. Wolfe (2003, p. 5) states “emotion is a primary catalyst in the learning process” and describes how the amygdala (a part of the brain) regulates emotional responses which can either facilitate or impede memory formation. A severely emotional experience facilitates memory formation in some way, whereas a bland or boring experience appears to impede memory formation.

The second approach in the analogy in Figure 2 leads to a justification of the memory enhancement technique used in this study, in that a technique that can provide an easily found label, keyed to a memory, could facilitate recall of that memory. For example, Scruggs and Mastropieri (1991) stated their opinion that mnemonic instruction improves recall by systematically integrating specific retrieval routes within the to-be-learned content. In other words, providing a piece of a pattern will allow the whole pattern to be retrieved by remembering the piece. For example, sohcahtoa is a meaningless word, but one I use to remember the trigonometry formulae. SOH-CAH-TOA reminds me than **S**ine is **O**pposite over **H**ypotenuse and so forth. The word leads me to recall the three formulae. Using the analogy in Figure 2, this is similar to putting a road-sign or arrow in place.

2.2.2 The Need For Learning Facts

O’Neill (1992, p. 5) stated “memorizing basic facts is often essential”. Similarly, O’Daffer (1993, p. 376) stated, “the learning of facts and procedures is a legitimate and important part of a student’s education”. It is probably not necessary to justify the contention that the educational process as it currently exists in our schools has an important component of learning facts. Even though a substantial part of school assessment (in Queensland at least) centres upon the higher cognitive functions, such as problem solving (which is discussed in detail later), there is still a requirement for students to learn and recall basic facts – at a trivial level even encompassing the meanings of the words used in describing the fact. Without the knowledge and recall of at least the relevant facts, students will probably not be able to demonstrate the learning or application of any higher-order skills. Thus, a student is unlikely to be able to demonstrate their postulated exceptional problem solving skills by applying them in a previously unexperienced context – a trivial example being the lower primary student with exceptional analytical skills within a Year 4 assessment framework being unlikely to solve complex nuclear physics problems – not from a lack of problem solving ability so much as from a lack of the basic factual concepts within which to frame a response.

2.2.3 Learning

Can a good teacher teach a poor learner? Bodner (1986, 373) stated "teaching and learning are not synonymous; we can teach, and teach well, without having the students learn". Generally, educational literature about learning looks at ways in which a teacher might facilitate instruction, that is, from the point of view of an external instructional source transmitting data to a receptive learner. Although constructivist literature deals with teachers being cognisant of student's misconceptions, it also is often discussed from the point of view of an expert attempting to work externally correcting something within the learner. From a different perspective, much has also been written about teaching how to think (e.g., de Bono's works as exemplified by de Bono 1976, 1992). Problematically though, if students do not learn effectively, they will not necessarily learn how to think either.

Fewer researchers have written about learning how to learn, or teaching students how to go about learning. There seems to be a general assumption that learning is an innate skill, in which one has an aptitude (or not), and the literature tends to focus more on how the teacher might work around a student's lack of ability to learn, without necessarily directly addressing the lack of ability itself. Surely we need to look at the assumptions made here. Perhaps teachers' work would be easier if there was a way of improving the students' ability to learn, rather than just facilitating learning using the student's inadequate learning skills.

Airasian and Walsh (1997, p. 446) report a perception that what we currently do in schools does not meet the needs of all students. This, I believe, is self-evident by looking at the success/failure rates currently held as acceptable in schools – even in high achieving schools there seems to be an acceptance that some students will not achieve well, or at least that few students will learn everything. It seems to me that if a student somehow acquires the ability to learn before starting school, they will do well. If they do not, there is little hope for improvement or achievement. An underlying consideration of my research is to address this issue, and test the possibility that we can actually teach skills, that through repeated practice, will assist the student to learn more effectively, efficiently, and with greater recall in regular science and mathematics lessons in school.

In order to justify the technique used in the study (the technique itself is described in detail later, and again in the appendices) as a suitable vehicle for this aim, I feel it necessary to analyse the learning process to identify sources of possible problems (or limiting influences) in learning. An effective training technique will have to remedy or alleviate as many of these perceived problems as possible. The validity of this analysis has no direct bearing on the study - it merely provides a framework within which to group various factors for further consideration. I present the following diagram (Figure 3) as my representation of the entire process of learning, with its various influences identified. In the diagram, I identify eight areas which I believe can affect the efficacy of learning and remembering. Each of these is discussed later, under *Barriers to Effective Learning*.

2.2.4 Understanding / Complex Reasoning / Cognitive Skills

It is the contention of this study that practicing recall techniques will lead to greater understanding and more effective higher cognitive functions, for example in science and mathematics. This claim requires justification from several perspectives.

2.2.4.1 What is meant by the term 'more effective higher cognitive functions'?

Ruberu (1982, p. 28) expressed the opinion that all learning can be classified broadly under two headings: habit learning or rote memorising, and intelligent learning or learning which involves understanding. Obviously, a parrot which has been taught to say $E=mc^2$ is probably operating at a different level of understanding to a nuclear physics post-graduate student, and this highlights what I mean by the two levels of understanding. The trend in education in Queensland over the past few decades has been to emphasise the 'understanding' type of learning over the 'rote' style, although it is necessary to acquire a considerable number of facts through 'rote' learning in order to demonstrate 'understanding'.

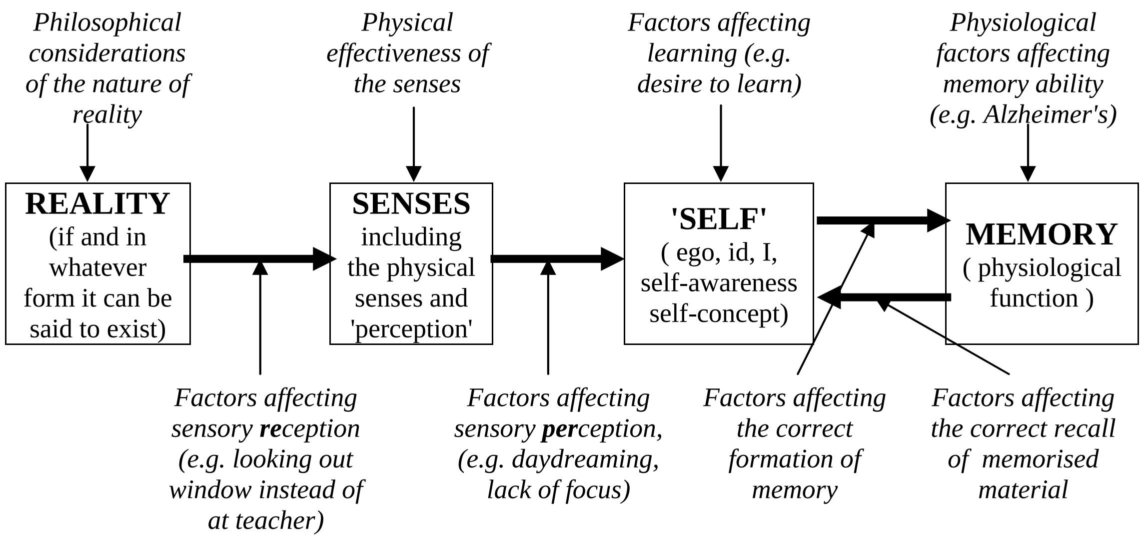

Figure 3: The process of memory formation and factors affecting performance

Similarly, Gunstone (1993) defines good science learning as that in which the student undertakes the tasks of integrating the new material with what he or she already knows and believes, extending what is being learned into appropriate new contexts, and monitoring the learning and progress.

General criteria for 'good learning' outlined by Biggs (1991, pp. 215-218) can be summarised as: what gets good marks, is adaptive not maladaptive, develops self-control (from a 'control of own learning' interpretation, not disciplinary), facilitates effective problem solving, and is student-centred. This link to effective problem solving allows the use of observed problem solving ability as an indirect measure of the effectiveness of learning.

Thus ‘more effective higher cognitive functions’ can be interpreted in an assessment context as ‘observed problem solving ability’. From my training as a panel member (who undertake the verification process for issuing Year 12 senior certificates) I am aware in Queensland senior science subjects that “teaching for the test” invalidates assessment of “complex reasoning skills”. (“Complex reasoning skills” is the term used in Queensland education (for example the Board of Senior Secondary School Studies Senior Chemistry Syllabus 1994) to describe a range of higher cognitive functions, but can loosely be defined as “skills required to answer questions needing more than simple recall or the simple application of a straightforward algorithm”). That is, if a student has seen a particular question previously, has had opportunity to practice answering it or has seen worked solutions, then that student’s ability to answer that question demonstrates a similar level of cognitive ability as the parrot saying “ $E=mc^2$ ”, and not necessarily showing “complex reasoning”. (An aside - the panel monitoring system for validating senior results in Queensland acknowledges that a particular question might be ‘simple recall’ or ‘complex reasoning’ depending on whether the teacher has demonstrated it to the students or not, and the panels have systems for detecting which is the case, based around how many otherwise low achieving students have a reasonable response to the question. It is presumed that “low achieving students’, that is, ones who do not recall much factual information, will not be able to provide an even partly creditable attempt at solving a complex reasoning type question, and that if several do, this indicates that the teacher has ‘taught the question’.)

2.2.4.2 Which is more important – problem solving ability or memory?

Eylon and Linn (1988, p. 275) state that knowledge of the subject matter is central to problem solving in the scientific disciplines. But they also state (p. 270) that a learner's level of interest in science, self-confidence in their ability to learn, and other psychosocial factors, all interact with each other, the science topic, and the learning context, to affect outcomes.

Similarly, Bransford (1979, p. 205) concluded "the ability to understand and remember is strongly influenced by the learner's currently available skills and knowledge". This statement implies that increasing a learner’s skill level (that is, in this researcher’s interpretation, their skill in learning) should result in an increased ability to recall.

As a school teacher, Stanbridge (1990, pp. 20-21) held a similar view when she stated

> Much of what passes for learning in school is little more than the rote memorising of formal knowledge (to which the student may not assign meaning), and the acquisition of algorithmic paths to problem solving. These tactics often ensure success at exam time but do little to enhance the usefulness of the material learnt or the student's ability to extend his/her range of understanding.

This statement highlights the importance of rote memorising to examination results. It is not the intention of this researcher to discuss the moral or social implications of Stanbridge’s statement. Discussions about whether it is ‘right’ to have an educational system dependent upon rote learning, or whether it is desirable (as is implied in Stanbridge’s statement above) to have a greater enhancement of the usefulness of information are outside the scope of this research. It is, however, relevant to acknowledge that our present educational system does have a high dependence upon the student’s ability to memorise and recall.

Thus, teaching students to more effectively memorise and recall, should achieve better educational outcomes. It follows then that memory, as exemplified by rote learning, may be more important than problem solving ability or understanding. At the very least, a person with no or very low memory ability due to brain injury is unlikely to succeed even in an educational system based solely on assessing ‘understanding’. It seems to follow that the ability to recall, or use memory, is at least a pre-cursor to demonstrating understanding; and that without memory, there will probably be no understanding. This concept requires further exploration.

2.2.4.3 What is ‘understanding’, and how does it relate to memory?

According to Nickerson (1985, p. 222), understanding is the extent to which the student can define a particular concept in an acceptable operational manner, and apply it successfully, in a similar way to how these demonstrations conform to those practised by competent professionals. In other words, this is comparable with the social constructivist idea that the 'truth' of one's concepts is determined by comparison to socially accepted 'truth' (Kim, 2001). In order to demonstrate ‘understanding’ then, it is necessary to ‘learn’ what is acceptable.

There is some support for the theory that all aspects of learning, understanding, and the higher aspects of cognitive development stem from the simpler aspects of memorising and recall. In outlining the Van Hiele theory, as it relates to the learning of geometry, Pegg (1985) used the five characteristic levels or stages that a learner passes through

- recognition (e.g. of shapes),
- analysis (recognition of shared properties),
- ordering (pairing or grouping of related properties),
- deduction (acceptance of proofs of intuitively recognised facts),
- rigour (acceptance of logical proofs of counter-intuitive facts);

and stated that a student's understanding (of geometry) must pass through each level in turn before mastery is achieved (assuming 'rigour' to involve mastery). He specifies that it is necessary for a teacher to teach within the framework that is appropriate to the students' level of thinking. Of direct interest here, though, is the (perhaps obvious) first step – that of recognition, which is related to learning and recall.

Furthermore, Blais (1988) discusses the change from novice to expert in terms of acquiring a skill of observing the essence of a thing. A novice is one who has not learned to observe. Mastery comes after more basic skill acquisition. That is, one has first to obtain or learn basic skills before mastery can be demonstrated,

To summarise, these latter few references indicate that ‘good’ (that is, effective) learning is indicated by the ability to solve problems. Problem solving in turn requires the development of understanding, and this understanding is indicated by the achievement of good learning and demonstrable ability. The interrelatedness of these three concepts is diagrammatically represented in Figure 4.

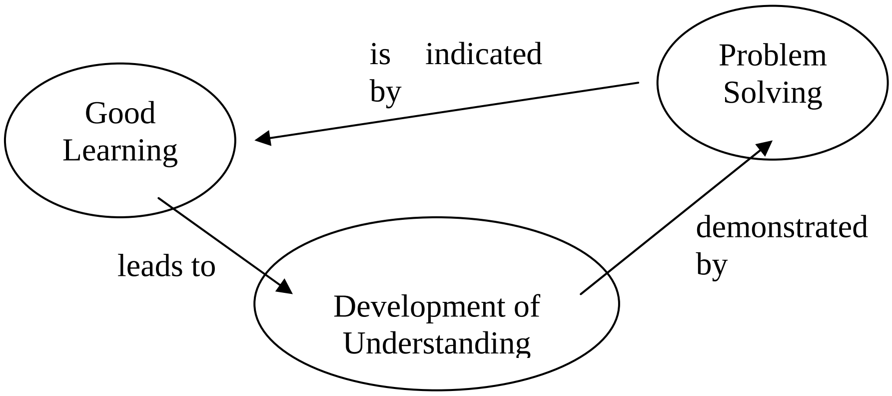

Figure 4: The interrelatedness of recall (learning) and cognitive ability (problem solving)

Thus it can be concluded that the more complex aspects of what we know as ‘learning’, that is the cognitive concept of understanding, may be related to and dependent upon the simpler skills of memorising and recall. Before asserting that these simpler skills are predeterminate of the more complex ones, we need to develop a better understanding of measuring understanding.

2.2.4.4 How can we measure ‘understanding’?

So, how do we know if a student understands something? As de Bono (1976, p. 200) stated "…testing thinking is extraordinarily difficult and beset with pitfalls." As teachers we set ‘problem solving’ questions on examination papers, but we do not necessarily teach problem solving skills, at least not directly. In secondary science and mathematics classrooms, there is a lot of modelling of problem solving, worked examples, and so forth, but do these successfully accomplish the goal of ‘teaching’ problem solving, or are they more likely a fancier type of recall? In Queensland, we have a panel monitoring system to moderate in-school assessments. One of the assessment criteria in the Senior Science syllabi (specifically those implemented between 1994 and 2004) is known as ‘complex reasoning skills’. It is accepted wisdom within these panels and in the general teaching community in Queensland that if a teacher were to show a student how a particular ‘complex reasoning’ question is done, and the student has practiced it, then it is no longer classified as a ‘complex reasoning skills’ question, but one of ‘recall or simple application’. The criterion ‘complex reasoning skills’ attempts to assess a student’s formal reasoning ability by judging whether such ability has been demonstrated in the student’s attempt to answer complex questions.

The differential perspective of learning (Eylon & Linn, 1988, p. 268) stated that it is very difficult to test formal reasoning ability because such ability is dependent upon the domain knowledge possessed by the reasoner - the knowledge held by the reasoner directly affects their ability to use certain skills related to that knowledge. Additionally, science proficiency seems to be related more to task specific skills than abstract intellectual skills (Eylon & Linn, 1988, p. 269). In other words, formal reasoning ability is dependent upon memorising or rote skills, as these are required to gather sufficient knowledge upon which to base the demonstration of formal reasoning. Put very simply, one cannot formally reason about something one knows nothing about.

Jacobson (1998) also stated that thinking skills, in turn, could not be evaluated without giving consideration to the process of memory. Efficiency of memory affects many of the skills necessary to be successful in school. Reading ability and comprehension are examples of school tasks that are mainly memory dependent, yet without these, the ability to demonstrate thinking skills is severely restricted. Jacobsen also stated that individual differences in reading ability seem to arise mainly from differences in the efficiency and capacity of working memory.

However, it appears that even the application of simple memory skills, such as rote learning, may entail higher cognitive processes when viewed from a constructivist viewpoint. Noddings (1990, p. 14), stated

> even when students are in what looks to be rote learning situations, they must perforce construct, because that is the way the mind operates.

The question this raises is whether the act of 'constructing', in the meaning used by constructivists, is actually a simple recall skill or a higher cognitive skill. Noddings implies the latter. I am going to assert the former, in that if we define the act of constructing a memory as a higher cognitive process, then we lose a definition to distinguish between memory building and what has been referred to before as demonstrating understanding or complex reasoning. I am willing to agree that memorising (constructing a memory) is not as simple as the term 'rote learning' implies, but it is still a simpler skill than what I mean by complex reasoning.

Nesher (1986, pp. 5-6) reported the results of two studies that show no correlation between tests measuring algorithmic performance in mathematics and understanding of the underlying principles when administered to the same sample populations. That is, the performance of students on a test of algorithmic application was not dependent upon their *understanding* of the principles involved in the algorithm. Is 'understanding', then, of less importance in learning than memory, or is this a demonstration of the ineffectiveness of conventional assessment techniques for measuring understanding as against recall? If current assessment techniques are predominantly failing to assess understanding in favour of assessing recall, then there may be justification for concentrating teachers' attentions on improving students' recall skills and abilities.

In contrast, Sachse (1989, p. 18) stated "concentrating on the teaching of "factoids" wastes students' time and erodes their motivation". Sachse thus highlights the need to remove items of information which serve no purpose other than to provide something to assess, and which are irrelevant to the students' needs. However, he does not explain how we distinguish between irrelevant facts and those that may provide answers to problems. It appears that our ability to solve problems may relate to the bulk of information we are able to recall – that is, the more we know, the more likely it is that we will be able to trigger a sufficient number of neurone patterns to 'find' an answer to a problem. Thus, can we truly say that any factoid is truly irrelevant?

Constructivism tells us that we learn by building internal constructs upon knowledge we have previously learned. It does not tell us how we remember. The Queensland Studies Authority state in the Senior Syllabi in the sciences (e.g Board of Senior Secondary School Studies Senior Chemistry Syllabus 1994) a belief in at least three distinct ways of demonstrating ‘remembering’:

- simple recall (e.g. remembering A=2πr),
- application of knowledge (e.g. calculating the area of a square with a side of 4 cm) and
- complex reasoning skills (involving complex problem solving, for example the application of known algorithms to novel situations).

As indicated previously, it is my contention that simple recall is a requirement that must be achieved before the other, and higher, cognitive abilities can be demonstrated.

2.2.4.5 Summary

It is of note that the direct and indirect implications from the above references are that recall or memory must occur before understanding. Simply put, one cannot understand something that one knows nothing about. I believe that understanding is probably tied into some sort of pattern recognition (Carter 1998, p. 170) where our brains form some sort of incomplete pattern, which then somehow magically has the gaps filled or partially filled from our store of learned patterns by the triggering of brain neurones through some physiological process as yet not fully understood. The mechanism for this happening is beyond the scope of this thesis, but the relevant implications are two:

- the more patterns that one has stored, the more likely one will find a partial match – that is, the more that is known, the more reliably will an answer or solution be found, or recall facilitated
- by improving the skill with which the patterns are matched (e.g. by practicing) the quicker will an answer or solution be found.

I therefore believe that there is theoretical support for the research question whether improving the ability to learn should result in improved performance in many if not all aspects of understanding. At least performance improved to the point where it is not going to be possible to readily distinguish the level of understanding of someone operating in a memory-enhanced mode from others who are not. I acknowledge that this is not conclusively stated in the literature, but if it were, there would not be the need to continue with this type of study.

We now need to look at how one can go about improving the ability to learn, or how we can teach someone how to learn.

2.3 Teaching How to Learn

Marzano (1992, p. 48) stated

> Cognitive psychologists have taught us a lot about storing information in long-term memory. In fact, we know more about how information can be stored for easy retrieval than we do about almost any other aspect of learning, Unfortunately, what we know is usually not taught in the classroom.

This statement neatly sums the intent of this research project – to instigate a connection between psychological knowledge and classroom pedagogy.

Hubbard (1989) questions the effectiveness of drill / rote learning of mathematical skills, but raises the issue of whether mathematical skills can be learned by repetition, as, for example, are sporting skills. While affirming the use of rote in learning tables, she questions whether repeated working of similar exercises can result in the understanding of more complex tasks (for example such as solving quadratics). My response is to ask whether there is any alternative, or even whether there is any other way of learning to 'understand' something other than by repeated practice. Campbell (1993), in reporting the results of a study in teaching learning strategies, concluded

> this study highlights the fact that success in improving students' thinking skills will require a long-term commitment and an emphasis on activities which engage students in thinking. (p. 15)

Campbell's research involved 12 sessions of theory and practice of specific skills, for example the skills of elaboration and making comparisons, with Year 7 students. This was achieved outside of the normal school curriculum.

In contrast, I propose that improving student’s thinking skills is dependent upon the student acquiring sufficient knowledge (by memorising) to firstly understand and secondly to demonstrate understanding by problem solving, and that this needs to occur, and be achieved, within the school and classroom setting.

With respect to science curricula, Watts and Gilbert (1989, p. 76) indicated that there are several assumptions generally made by curriculum writers: that [subject-specific] literacy is good for all, that all subjects are learnable by all, and that in the current school situation all subjects can be taught.

The second of these assumptions - that all subjects are learnable by all students, is not something I would wholeheartedly assert. Piaget, for example, would probably have said that upper high school subjects involving formal skills could not be learned by students operating in a pre-concrete thinking way. At the extreme, a young child is unlikely to be able to construct solutions to complex nuclear physics problems even if the child had been taught the relevant facts. When presented with a tall 250 mL measuring cylinder and a short 500 mL beaker, and asked which one would hold more water, my experience is that an 9-year-old is more likely to pick the cylinder whereas a 13-year-old is more likely to pick the beaker. This experiment was described by Samuel and Bryant (1984) and a similar example was also outlined by Piaget and Inhelder (1967). This corresponds to the Piaget transition from concrete to pre-formal thinking, which he links to changes in brain organisation and thus thinking skills. My point is that there seem to be some high level cognitive functions that the immature brain is not capable of performing. This in turn leads to an understanding that the brain does undergo some functional changes during growth and maturity, which leaves open the possibility that these changes may be facilitated, advanced, or enhanced by a suitable training program.

This poses the question of whether it is possible by good teaching to assist a student to move through the developmental stages of brain organisation. That is, is it possible for a teacher to accelerate or facilitate faster transition between the stages? Hand and Vance (1995) outline broad principles for the teacher wishing to implement a constructivist approach to their classes, but much of their work deals with how to cater for the student's construction of concepts, for example by group work. The assumption is that learning occurs because the teacher is presenting activities and material in a way that facilitates easy learning by means of the constructivist model, but the article has little to offer if the students are not at a stage of being able to learn. Like many other articles, the approach is for the teacher to make it easier for students to use their existent learning skills, rather than to improve or acquire those skills. Therefore we can expect that even in the most brilliant and effective teacher's classroom, a student with deficient learning skills (even, if necessary for an example, to the point of brain-injury type problems preventing learning) is *not* going to learn.

Gorrell (1993) researched the effect of cognitive modelling on the acquisition of problem-solving skills – and showed that providing a cognitive model, by, for example, having the teacher think aloud increased the student's learning the skill. Butler (1993) also outlined some practical examples of how to model thinking skills, and clearly set out some processes for thinking. Both authors assume that the student will learn the thinking skill from observing the teacher, which does not directly address the issue of how to improve learning skills. By this, I mean that these authors focus on students learning from the observation of teachers who model and demonstrate appropriate strategies, without addressing the basic concept of whether the students actually can learn that way. There is an assumption that by modelling actions, children can learn those actions. I do not intend to dispute these assumptions here, but merely point out that there is literature support for the idea that one can assist students to learn how to think.

In a challenging and critical book, Glasser (1969) suggested that schools are designed for failure, in that those who succeed are usually those who can respond in ways required by the teacher. Those who cannot (or will not), for whatever reason, respond in the 'correct' way are deemed to have failed. Failure leads to a poor selfimage, which disinclines the student to further effort to learn. I recall many years ago, the ‘solution’ to a class of students who demonstrated little ability to learn was to segregate them into a special class and teach them ‘simpler’ stuff – yet the majority of them still managed to fail, regardless of how ‘simple’ the material was made. I believe the problem was not to be found in the assessed material being too hard or too complex, but that the students had not learned to learn, and were therefore doomed to failure no matter how easy the work became. Indeed, in one experiment, I gave the students in the lowest of several streamed classes the questions and answers to a practice mathematics test a week ahead, and went over the question and answers in class, modelling and providing solutions repeatedly for six lessons leading up to the test, and still had a class average of E+ on exactly the same test under examination conditions! I now believe that the time would have been better spent directly addressing these student’s learning abilities rather than trying to make the mathematics as easy as possible.

As a teacher of over 20 years experience, my perception of schooling is that it is, at least in part, a sorting process whereby students are increasingly labelled and differentiated. By Year 12, we have identified those who have learned the skills of learning (and permit them to enter university) and those who have not (who may go into less academically demanding employment). But how much do we actually teach students how to learn? There are some things commonly done by teachers, such as enforcing quiet, maintaining attention, setting required reading tasks, ensuring note-taking, requiring summarising, and setting homework, but do these actually help a student to learn how to learn, or just make it easier for their learning aptitude to be expressed?

De Bono (1992) proposed some practical exercises on developing thinking skills, but these are pre-dependent upon sufficient knowledge about the topic. For example, the seven coloured hats, and the PMI (plus-minus-interest), CAF (consider-all-factors), and the other techniques all require the thinker to generate relevant concepts - and this is not likely to happen in circumstances where the thinker knows little about the problem. In the most trivial sense, lower primary school students are not going to solve a simulated crisis in a nuclear power plant, no matter how well they have mastered the principles of de Bono. However, Edwards (1988) reported research using the de Bono CoRT-1 program within a science framework, in which a statistically significant increase in I.Q. (p. 27) as well as statistically significant increases in academic achievement (notably in the humanities but not the sciences) compared to a control group were obtained. So while there is much benefit in teaching de Bono's thinking skills, these skills do not apparently teach *learning*, and do not supersede the need for learned knowledge.

There have been some attempts at directly developing cognitive skills. Endler (1999) reported the success of the *Cognitive Acceleration through Science Education* project in developing student cognitive skills, but noted (pp. 2-3) that students develop at different rates, and to a different extent. In a similar vein, but a smaller study, Garnett, Hackling, and Silver (1990) reported the results of research into an attempt to increase students' scientific reasoning skills by direct intervention and specific training in those skills. Their results showed a significant increase of skill in the treatment group, but of more interest is that their control group also showed a significant increase, which they attributed to either increased maturity, learning through experience with the pre-test, or development within their usual science classes, or some combination of these factors. Nevertheless, their test of significance indicated that there was an effect of the treatment over and above the increase of skill in the control group.

In research into the use of mental rehearsal on increases in musical performance, Theiler and Lippman (1995, p.329) concluded '…that mental practice may facilitate cognitive coding and help to create optimal levels of attentional focus and arousal.' That is, mental skills involving increased focus and visualisation increased the performance of learning musical pieces significantly. The authors give several hypotheses in explanation and quoted the work of many others.

From an analysis of the above, I conclude that there is some direct research into improving learning, and much of what there is incorporates an assessment of thinking skills generally in either the training or the data collection. Theiler and Lippman (1995) provided some justification for seeking a method of teaching learning using mental rehearsal in science education, which is my intuitive solution, that one should teach learning by providing learning exercises to practice. This concept of learning by practicing learning underpins the focus of this study.

2.4 Barriers to Effective Learning

Strydom & Du Plessis (2005, p. 1) stated

> In order to learn, a person must be able to store something that he has perceived or decoded, so that he will be able to recall this information at a later stage. It is the ability to record to memory or to remember that makes learning possible.

The process of storing and retrieving a memory is central to any discussion about learning and memory training techniques. In determining the potential worth of a memory training technique, we need to establish the criteria under which to assess possible candidates. To do this, I refer in turn to each of the eight areas of effect on the learning process identified in Figure 3: The process of memory formation and factors affecting performance, above.

2.4.1 Philosophical considerations of the nature of reality

Discussion of the nature of reality is somewhat beyond the scope of this study. Of some relevance is to note that early constructivist epistemology stated that the only valid reality is the internal construct that an individual makes to represent the world, and that this construct often influences the nature of the perception of 'reality' by the perceiver. Thus the learner actively constructs a reality within him or her, rather than the objectivist viewpoint of the existence of an external reality in the traditional sense, with an internal (albeit not perfect) representation of that reality. This principle is referred to in articles by Noddings (1990, p10.), Cobb et al (1992, p. 22), Solomon (1992, p. 142), Ernest (1995, pp. 461-462), and Taylor (1996, pp. 154 - 155), and to a lesser extent in Von Glasersfeld (1990, p. 22) and Tobin and Tippings (1993, p. 3). I have represented this principle diagrammatically in Figure 5, below.

The exact physical nature of the postulated internal reality is at best a contentious issue. We have, on the one hand, popular literature in self-improvement espousing the concept of mental imagery in terms of, say, a mental 3-D movie screen (Heibloem, 1990), whereas peer-review papers from psychologists and researchers skirt the issue of just how we hold or store internal representations. For example, Barrett (1989, pp. 83-93) cites and discusses over two decades of references to the work and theories of researchers such as Ray, Dennett, Ryle, Kosslyn, Fodor, Pylyshyn, Shepard, Block, Pomerantz, Anderson, Clark, Chase, Reid, Reed, Bemu, Wundt, Paivio, Cooper, Carpenter, Ball, Reiser, Finke, Mitchell, Richman, Pinker, Simon, Chomsky, Gardner, and Shebar without drawing any firm conclusion about the physical nature of mental images, but pointing out the difficulties and conflicts to be overcome in so doing.

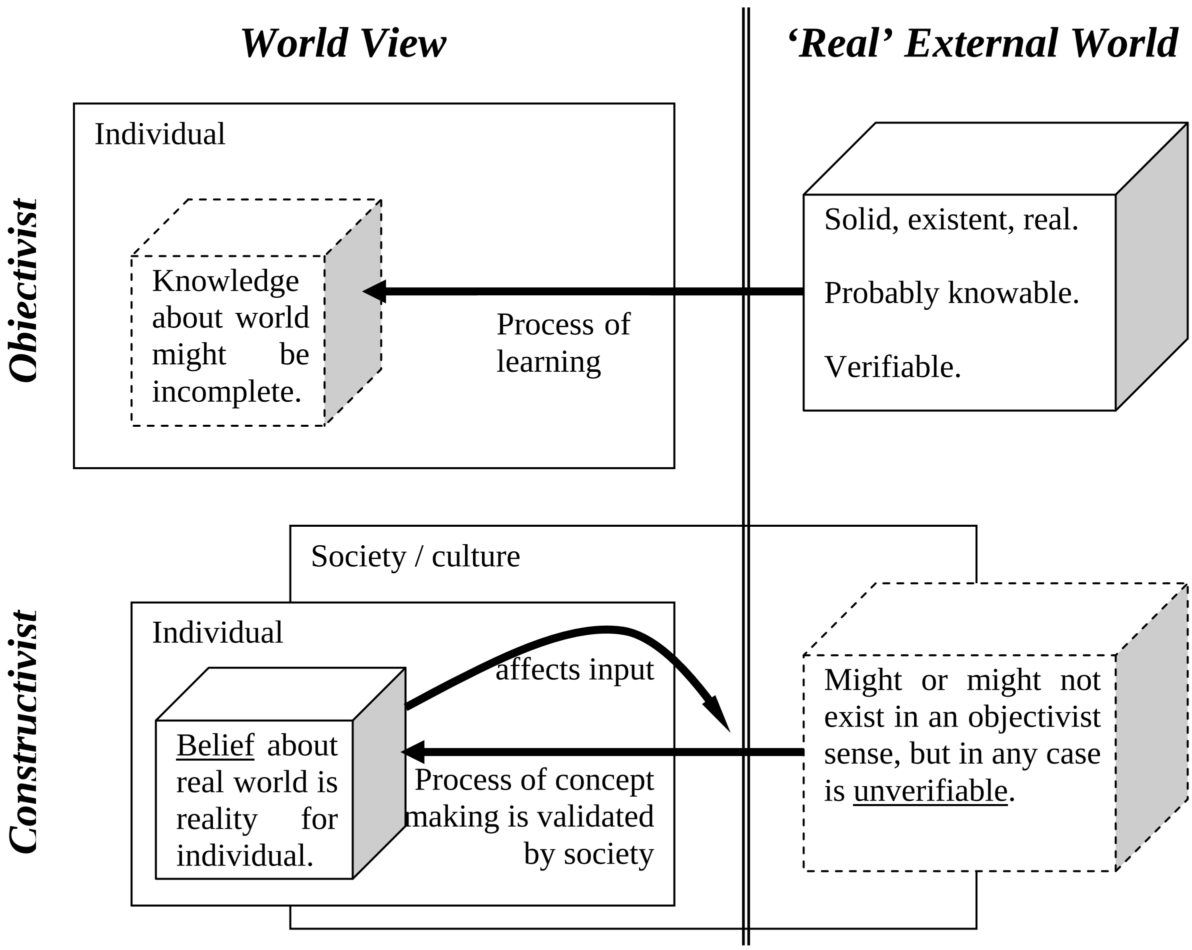

Figure 5: Constructivism versus objectivism diagrammatically represented

An aside, the controversial method of the retrieval of 'suppressed' memories and the now accepted likelihood of implanting 'false' memories shows that our memory system does not distinguish between 'real' and ‘vividly imagined’ data (Youngson, 1988, p. 244). In other terms, we do not have an in-built reality-check for Truth in an external real-world sense; rather we have some system for assessing perceived or presumed truth based upon our own prior experience and established beliefs. From a memory perspective, there is validation here for the concept of misconceptions or alternative constructions that are central to the constructivist epistemology. There may be strongly held beliefs in memory that are at odds with Reality or Truth in whatever real sense they are associated with the capitalised terms as absolutes.

One thing that is deducible, however, is when our memory works, it stores some form of complete schema by which I mean a sensory-rich and emotionally charged impression incorporating as much data as a real experience presents us with. The concept of memory as a sensory-rich schema or gestalt was proposed by Gestalt psychologists, outlined, for example, by Wertheimer (1961).

Now consider two experiences - the first a near-death experience of being attacked by a savage beast, the other listening to a teacher talk about the quantum model of atomic structure. Which is more 'memorable'? I maintain that the latter experience is very sensory-data-deficient when compared to the 'real' experience, and I believe that it is this fact that limits later recall of the latter experience, and indeed, the bulk of class work. The attack by the beast carries sensory rich data: smells, sights, and more importantly strong emotional sensations of fear and pain. As previously discussed, when the analogy of memory formation and recall shown in Figure 1 is considered, the more intense experience is surely more memorable.

Thus any training method for improving learning needs to create a more valid, more 'real' experience, by incorporating as much sensory and emotional input as possible. Ideally, the memory to be ‘learned’ needs to incorporate all sensory data (sight, sound, touch, taste, and smell) as well as an emotional component (fear, anxiety, love, or humour). Intuitively, this seems correct, as a short reflection will easily bring to mind memories of great pain, stress, happiness, or scenes of mayhem or beauty, whereas details of mundane events may well escape easy recall.

2.4.2 Factors affecting sensory reception

In discussing the results for investigations into exemplary teacher practice in mathematics, Tobin and Fraser (1988) made four assertions that exemplary teachers used management strategies which: facilitated sustained student engagement, encouraged students to participate in learning activities, increased student understanding of mathematics, and sustained a favourable classroom learning environment. These authors concluded in part that most exemplary teachers believed that students had to be *involved* in order to learn in a meaningful way. Microteaching skills as espoused, for example, by Brown (1975), Macleod and McIntyre (1977), and Ananthakrishnan (1993) focussed on the development of teaching skills to capture and maintain student *interest* and *attention.*

It should be self-evident that a student who is looking out of a window while the teacher is demonstrating something on the board, or laboratory bench, is not going to remember much of what the teacher did! Thus, an effective memory technique must focus the learner's attention on the task at hand. This position also fits with the constructivist assertion that learning involves active construction, not passive reception; e.g. see Noddings (1990), Cobb et al (1992), Solomon (1992), Ernest (1995), and Taylor (1996). Learning requires active and energetic participation, at least of the learner’s mind and brain. I personally believe that this concept of not paying attention may prove to be the number one barrier to effective learning.

2.4.3 Physical effectiveness of the senses

Physical effectiveness of the senses is also beyond the scope of this research, other than to note that, for example, without doubt it is obvious that visual techniques might prove less effective or be ineffective with persons who were born blind. My personal experience and opinion suggests that the important factor is the construction of an internal representation of reality, and that therefore in the case of a person born blind, all such constructions would equivalently be missing visual stimuli. Therefore a learned concept in a school setting would not be any less rich or memorable, with respect to the missing sense, than any other experience. I suspect, therefore, that sensory deficiencies would not be an important factor in learning the proposed technique, other than the obvious problems to be overcome (such as using sign language to communicate with a deaf person). Since none of the participants in the study had any sensory deficiencies (and since I have no personal experience teaching the technique to persons with such deficiencies) this suspicion remains untested.

2.4.4 Factors affecting sensory perception

Bodner (1986) reported an experiment by Von Foerster in which a single word was repeatedly played at loud volume, and how participants started 'hearing' other words expressed, after 50-180 repetitions - and that over 750 alternative words were perceived, even though there was no change in the word being played. It seems that our minds seek diversity, and are willing to manufacture or misinterpret sensory data in order to avoid boredom. Any experienced teacher would be aware of the tendency for students to seek stimulation in boring situations!

There is also the constructivist concept that the internal reality interferes with the acquisition of new learning if there is a conflict between the internal construct and the new data, and much has been written about the robustness of misconceptions and the difficulty in helping students re-examine or modify them (see, for example, Ben-Zvi & Hofstein, 1996; Mansfield & Happs, 1996; Hewson, 1996; Schecker & Niedderer, 1996; and Grayson, 1996). Figure 6 illustrates diagrammatically how a pre-conceived idea firmly held by a student can modify the sense of what a teacher is saying so that rather than experiencing a cognitive conflict leading to conceptual growth or change, the student retains or reinforces his or her own concept.

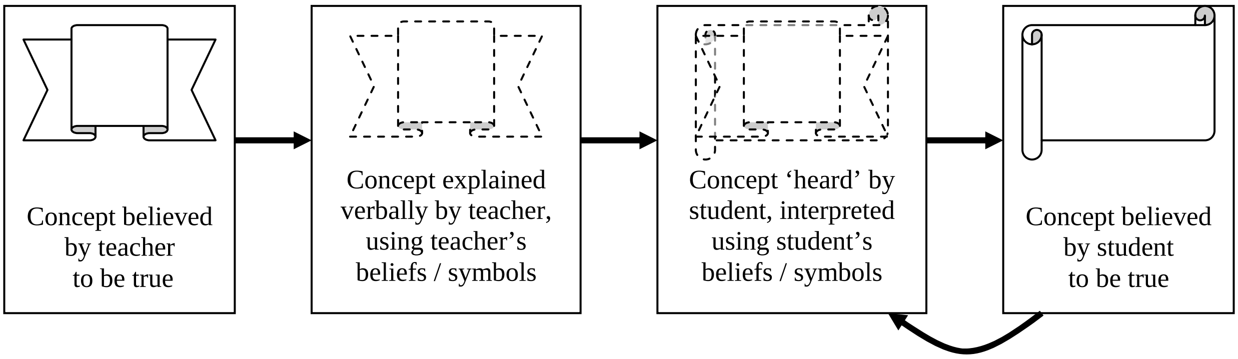

Figure 6: Attempted communication of concepts

Cooper (1998, p. 2) presented two interesting examples of how we interpret what our senses are receiving, which I have re-presented in

Figure 7. The first line is commonly read as “The Cat” even though the second symbol of each word is exactly the same. Theoretically, one should see it as “The Cht” or “Tae Cat” but our minds interpret what we ‘see’ in a way to make sense of it. Somehow our brains override the data received by the senses to interpret the same symbol differently in order to create sense of the words. We have no difficulty interpreting the symbols in the second line of

Figure 7 as ‘a’ even though they are different, and even though we might never have seen exactly that symbol font before. In discussing this latter scenario, Cooper also mentioned how we are able to read the handwriting of people whose writing we have never seen before, even though their form of writing may be significantly different to any we have previously seen. Sensory data therefore appears to be subject to some form of interpretative translation by our brain or mind.

1.

2.

Figure 7: Examples of Interpretation of Sensory Data

The preceding ideas warrant concern that what we perceive is not necessarily what our senses receive but is susceptible to 'incorrect' interpretation, for which there is no internal validation process.

Pinker (1997, pp. 211-298) provides, with examples, an excellent discussion on how easily our senses can be 'fooled'. Here is a physical example. If you were to gather three pots of water, one hot, one room temperature, and one icy cold, and place your left hand in the hot and your right hand in the cold for a few minutes, and then place them both in the pot at room temperature, you would experience your hands sensing that the water was at noticeably different temperatures even though you see that both hands were in the same pot.

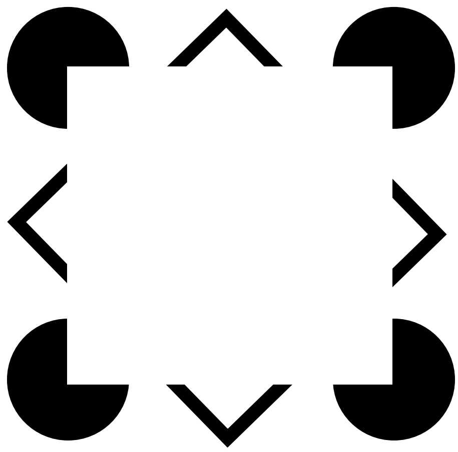

Figure 8: A simple illusion - there is no white square, only eight black objects

Figure 8 shows a simple optical illusion. The white square which is so 'obviously' there is actually not, it is probably being supplied by some part of your brain in an effort to simplify or make sense of the black shapes, thus to your brain a 'white square' on top of four circles and a heavily outlined black square makes 'more sense' than eight unrelated strangely shaped objects. This illusion follows from the "Law of Closure" proposed by Wertheimer (1961) as part of his description of Gestalt psychology, in which he suggested that humans attempt to make sense of what they perceive using a predictable set of principles, in this case by 'completing' the pattern formed by the four angles to make a square, and completing the three-quarter circles to make full circles. Having done so, our minds need the presence of the 'white square' in order to complete the logic of what we see, and to explain why there are pieces missing from what we assume is there.

Even the sense of taste can be easily fooled. Eat a spoonful of your favourite breakfast cereal, without milk. Then eat a spoonful of sugar, letting it absorb into your taste buds. Take another spoonful of cereal and you will find that the taste will change considerably. The greater the sugar content of the cereal, the more pronounced the difference would be. The reason for this is just as looking at a bright light overloads the retina and causes the illusion of a dark after-image, a spoonful of pure sugar overloads the taste sensors on the tongue, temporarily reducing their effectiveness, leading to a "sugar-free" taste when trying the cereal.

These examples highlight that we can be fooled into misinterpreting data received by our senses. That is, we can never be sure that our senses are revealing the 'Truth' of reality. There appears to be substantial risk of misunderstanding reality based on our sensory data.

It is the contention of this thesis that a memory enhancement technique should reduce the risk of this misunderstanding. However, one can not see how this can be readily achieved because it depends so much on the internal preconceptions of the learner and the effect and exact nature of these is not readily observable or assessable.

2.4.5 Factors affecting learning

Leavitt (1971) identified the following factors as motivations for effort generally - money, food, shelter, goods, peer group acceptance, power, morality, knowledge and understanding, security, and accomplishment. For the students in a classroom, only two of these factors are immediately relevant - peer group acceptance and knowledge and understanding - and unfortunately, with the prevalence of the tall poppy syndrome, the former often works against the latter!

Garbarino and Asp (1981, p. 59) stated:

> Academic ability is a liberating factor for a child or adolescent. The greater a student's ‘pure’ ability, the easier it is for him or her to meet the basic academic demands of schooling and thereby achieve school success. Students with marginal ability have less latitude in schools because they must be better organised and motivated to meet those basic criteria of academic mastery that are required for school success.

The authors then discussed the odds of success at academic study taking into account several factors, including I.Q. and socio-economic status, and pointed out evidence that social factors are more important than cognitive ability in academic success, concluding that there are three fundamental conditions for school success. These conditions are the child must be allowed to attend school, the child must attend to and process academic information, and the child must display an accommodation to the rules of social behaviour governing the school. It seems obvious to state that learning will not occur in an unwilling learner, but this simplistic statement serves to introduce the importance of motivation.

Banks and Finlayson (1973, pp. 182-185) investigated the role of motivation to succeed in relation to academic achievement, and (perhaps not surprisingly) found that, although they identified several contexts within which motivation may have been instigated, motivation was directly related to academic success. They also identified that expectation of success (pp. 41-65) is an important consideration, and concluded (pp. 177-185) that amongst other factors, there is a need to develop a comprehensive theory of motivation. Of relevance is their finding that unsuccessful boys (their research took place in a single-sex environment) found that homework took more effort than for successful boys (p. 183). Although Banks and Finlayson indicated several possible distractions, I believe that it may be that the underlying cause was that these boys never learnt to learn easily. Having not learnt to learn easily, children do not put in the effort to learn, which means they do not learn to learn efficiently, leading to a defeatist spiral.

In discussing student self-concept, Burns (1982, chapters 8 and 16) identified several areas in which a poor self-concept can interfere with learning, and from a Rogerian psychological perspective outlined several guidelines for enhancing a student's self-concept as a means for improving academic performance and classroom behaviour. The students' self-concept about their ability to learn can, if it is a poor one, preclude the students putting in sufficient effort to learn. By not putting in sufficient effort, they do not achieve, which reinforces their self-concept as a poor learner. This concept is illustrated diagrammatically in Figure 9. This idea also provides a possible example of the previously discussed idea of self-perpetrating concepts.

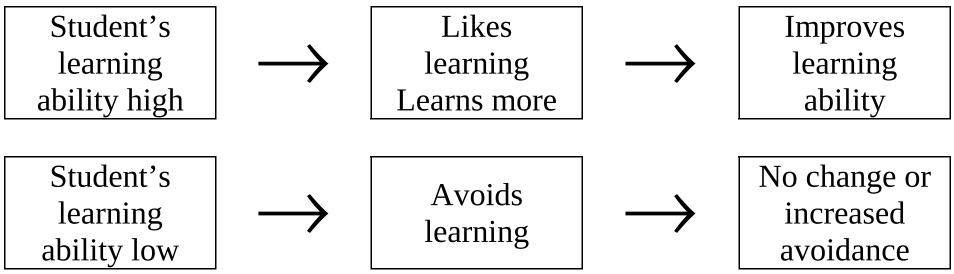

Figure 9 : Self-promoting and self-defeating learning cycles

Dye (1974) discussed the alienation that some students feel from the educational process, which leads to them not learning. Driver (1990, p. 6-7) stated that

> Games are a powerful motivating force leading to the development of positive effects … enhance … their mathematical knowledge and their personal understanding.

The concept of *fun* as a motivating factor cannot be ignored. Experienced teachers are aware that games and fun can be used to great effect in assisting learning. In developing a memory, it has previously been stated that emotion is part of the schema or gestalt, and here is more evidence that good emotions can be as effective as those of fear and pain. A memory technique that involves humour is going to be more readily acceptable than one involving hard tiresome work, pain, or fear. What is needed then is a learning technique that is: fun, or humorous, to maintain attention; easy, so that all students can master it, and unassailably affirms the student's ability to learn.

2.4.6 Physiological factors affecting memory ability

Physiological factors adversely affecting memory ability (e.g. Alzheimer's disease) are also outside the scope of this research project (which deals with presumably unaffected young people in a school environment), other than to note that if the investigated procedure is effective in increasing the efficiency of the learning process, there may be some application for those suffering various forms of physiological memory loss. That is, if one can learn to increase the efficiency of memory, one might be affected to a lesser degree by partial memory loss relating to physiological problems. Buzan and Keene (1996) stated that there are techniques for improving intelligence and memory, and that age does not have to see a reduction in either. They also quoted examples of aged persons who are mentally active to a degree well above the average younger person. Claire, Wilson, Carter and Roth (2002) reported success with utilising simple systematic memory training in helping people with early-stage Alzheimer's disease. However, Stigsdotter-Neely (2002, p. 1) reported that individualised memory training had only 'humble effects' upon patients suffering dementia.

Whilst investigating the treatment of cognitive training on severe physical injury cases, Salazar, Warden, Schwab, Spector, Brayerman, Walter, Cole, Rosner, Martin, Ecklund and Ellenbogen (2000) found that the training did not overcome the effects of traumatic brain injury. My experience in providing cognitive training to 'normal' aged adults lends some support to the conjecture that memory can be improved, in that I have heard anecdotal stories from elderly people in support of this. In the event of traumatic brain injury, there may be some benefit in improving the efficiency of the remaining brain, but this is again outside the scope of this research.

2.4.7 Factors affecting the correct formation of memory

Firstly, is it possible to fill up a person's available memory space? There seems to be no practical limit on the amount of information that can be stored in long-term memory, that is, learned (Cooper, 1998, p. 7), although there probably is some physical limit. Indeed, there is much evidence to suggest a practical limit on short-term memory. Cooper (1998, p. 1) stated “working memory … is extremely limited in both capacity and duration.” Golbeck (2002, p. 3) stated various memory principles, in a discussion of computer interface design, such as that short term memory is limited to seven plus or minus two chunks of information, and is volatile, and that users will often forget in the presence of distractions.

This average of seven items of memory is reported elsewhere as well, but Buzan and Keene (1994) described examples of persons able to recall much larger numbers of items, so it is probably more correct to say that the *untrained* person can store 7±2 items in short-term memory. This presumption then leads one to wonder what limit there would be on a *trained* person’s short-term memory. I know of a person who demonstrated an ability to memorise and recall (with greater than 90% accuracy) lists of up to 700 unrelated objects using the memory technique used in this research. Cooper (1998, p. 2) described a process of chunking whereby a large set of information is broken into chunks. Thus he indicated that a phone number of 8 digits is hard to remember, but the same number, broken into, for example, two chunks of four digits, is easier to remember. The implication from this is that the room available in those 7±2 short-term memory storage spaces might not be only large enough for a single bit of information, but may contain a sizable chunk of information, provided the brain/mind identifies it as a single piece. The person mentioned above who can cram 700 items into short-term memory may actually have been remembering a single chunk which comprises a list of 700 objects!

Chandran, Treagust, and Tobin (1987) investigated the role of four cognitive factors in chemistry achievement (formal reasoning ability, prior knowledge, field dependence / independence, and memory capacity). Of relevance here is that they found no correlation between achievement and memory capacity, the latter as measured by the Figural Intersection Test (by Burtis & Pascual-Keone). Chandran et al. reported (p. 149) that more than 90% of the subjects obtained the maximum score on this test, so that lack of variability made the calculation of reliability irrelevant. Under limitations they point out that the instrument used to measure memory capacity may have contributed to the non-significant results because the instrument may have been unable to differentiate between the students.

If memory *capacity* (meaning the total number of things that can be remembered) is not necessarily a predicate of achievement (at least in terms of non-brain-dysfunctional people), it would seem reasonable to suspect that memory *efficiency* (meaning the effectiveness of storage and retrieval) would be. It appears from current theories, as discussed earlier, that memory is some form of neurone-based pattern in the brain, and that the formation of memory involves strengthening or forming new interconnections between neurones. The memory is then retrieved (somehow) on the basis of partial pattern recognition – that is, one forms a partial neurone pattern, and the brain 'automatically' fills in the missing bits. Without going into this area any further, it is apparent that correct memory formation will involve laying a pattern in such a way as to make its retrieval simple and quick.

It is conceivable that the best way of ensuring quick and simple retrieval will be to establish a particularly clear, precise, and distinguishable pattern. Compare this to the analogy of memory formation and recall using the hidden square shown in Figure 1, earlier. Since we presume that the pattern is an experientially based pattern, it would involve sensory-rich and emotional data. From this, I postulate that effective memory formation will be enhanced by focus and clarity of thought, and interfered with by distractions such as loud music, conversations, or interruptions.

I present an analogy to clarify this point. If the memory storage area of our brain is something like a filing cabinet, then each memory is a file, and is labelled with some indicator of its contents. Memory retrieval is the act of finding the correct file in the cabinet. Memory formation is the act of creating and labelling the file. The file will be automatically labelled according to some arcane system independent of unfocussed intent. Thus if one listens to loud intense music while studying, some of the items of data will be filed under (or linked to) the song, the singer, the music, and some under the subject. Quick access (and recall) may therefore prove somewhat difficult! Of note is that there is a memory training technique called Superlearning in which the learner studies while listening to certain forms of music, and consciously linking the studied material with the music. Recall of the material is aided by first recalling the musical piece played while studying. In this, the music becomes part of the indexing system as a result of the conscious linking of the material to be learned and the music. If listening to music without the deliberate use of the Superlearning process, the material is filed haphazardly, which although not precluding retrieval, makes easy retrieval problematical, especially under the time and stress constraints of a test.

Carter (1998), Rupp (1998), Buzan and Keene (1994) also discuss the brain/memory structure in terms of short-term and long-term memories. An important concept in discussing the use of memory training techniques is the need to review material about 8-12 hours after first ‘learning’ it, and again about 2-3 days later to move the material from short-term memory into long-term memory. This approach is contrary to the popular technique used by students of ‘cramming’ the night before a test. This ‘cramming’ technique might work from the point of view of holding the material in short-term memory for sufficient time to pass the test, but the material will not necessarily be transferred into long-term memory. Hence the student will ‘forget’ the material shortly after the examination. I further postulate that problem-solving ability, being noticeably lacking in the exam-crammers of my experience, may well be based primarily upon material in the long-term memory. Since cramming can only utilise short-term and medium-term memory, the material stored there may be unavailable for utilisation in problem solving.

2.4.8 Factors affecting the correct recall of memorised material

Apart from brain injury or disease, there may be little preventing the correct recall of material properly learned. Carter (1998) listed many brain dysfunctions that prevent memory formation, but only some specific injuries or diseases that prevent correct recall. Rupp (1998) discussed memory loss to great length. However, much of what the situations she described can be attributed to the subject either not having learned the information properly or to the recall confusion as espoused previously (as illustrated by the hidden square in Figure 1). Landrum (1997) noted in conclusion to a discussion about implicit and explicit memory, that the ability to recall pictures implicitly does not decay over time (for the short periods studied), even though explicit-memory decreases as expected, but again this is explainable by the confusion effect. Bransford (1979, pp. 52-53) reported research that suggests that the inability to remember is a result of the way that the input information is processed, that is, learned.

I believe that two significant adverse effects on recall are stress and negative expectancy. Heibloem (1990, p. 55) reported that Dr Richter of Johns Hopkins University in the USA found that our brain cells operating in a predominantly beta brain rhythm fire haphazardly in a desynchronised scattered way whereas at alpha [a slower brain rhythm achieved through relaxation] they become synchronised and fire together. Since recall involves a more relaxed brain state (Heibloem, 1990; Honzatko, 1985) and stress creates a less relaxed brain state, the stress of being called upon to provide an answer can reduce the probability of correctly recalling it. Hence the existence of 'exam stress' and the situation where, when one relaxes on leaving the examination room, the answer to some particularly difficult question is suddenly remembered.

Withes (1991, p. 25) pointed out that success in a test is a matter of confidence, desire to do well, and the feeling you can, as much as a test of knowledge. By referring to negative expectancy above, I refer again to the constructivist concept that holds that constructs can filter and affect the perception of incoming data (see section 2.4.2). If one holds the impression that one cannot recall certain types of knowledge, then one is less likely to be able to recall that knowledge. I have often heard otherwise sensible students assure me that they cannot learn science (or mathematics) no matter how hard they try – and, not surprisingly, their examination results tend to prove them right! I once taught a student who could correctly sing the complete lyrics of several recently released punk and heavy-metal songs – which he would distractingly do often in class – tell me that he had a very bad memory, and could not possibly remember that PV=nRT!

A successful training technique should involve a relaxed approach, and provide or promote self-confidence in one's ability to recall and learn. In the latter concept, the ability to prove to the learners that they are capable of learning unrelated, difficult, and irrelevant material should lower or remove their opinion that they are ‘incapable of learning’, and result in increased self-confidence, a reduced state of anxiety, and thus better recall.

2.5 Literature Support for Memory Enhancement Technique

2.5.1 For Memory Techniques

Rupp (1998, pp. 52-55) reported research that indicates that the short-term memory can typically hold seven, plus or minus two, unrelated items. Yet some people are capable of prodigious feats of memory, for example memorising the order of a deck of cards in 59 seconds, or recalling a list of over 100 digits (Buzan & Keene, 1994, p. 247). The difference is explainable in terms of the training and practice utilised by the latter group. Although some persons of exceptional memory seem to have developed it innately, most relate that they use some ‘trick’ acquired through conscious effort and repeated practice. It is feasible, then, that memory can be improved. Further evidence of this is given by Doidge (2001), who reports success in teaching memory techniques to children with learning disorders with subsequent improvement in learning ability, and the reduction or elimination of drugs. Also, Claxton (2000, p. 19) outlined claims for the effectiveness of visualisation in increasing the quality of student’s creative work and mentioned the improvement in short-term memory.

While discussing Piaget, Novak (1978, p. 29) reported that teaching young children formal operational concepts leads one to the conclusion that a correctly designed series of learning experiences could conceivably accelerate students’ progress through their intellectual development. Since the Piagetian stages of development refer to cognitive process, this lends some support that these processes are acquired – that is, they are not solely dependent upon genetics, and therefore they might be improved with suitable training.

Carney and Levin (2002) suggested that “mnemonic strategies facilitate students’ learning of higher-order information” following their research in which they attempted to teach taxonomy by using a mnemonic process. Scruggs and Mastropieri (1991) conducted research on the teaching of science using a mnemonic process, in which visualisation of concepts was a key technique. They concluded:

> In this investigation, it was found that mnemonic instruction can produce strong and lasting effects on the acquisition and maintenance of science content. As seen in previous research, the effect of mnemonic instruction was not only statistically significant, but exceeded by a wide margin (nearly two to one) learning by more traditional, strategy-free instruction. Comparison of student strategy reports with performance information provided further evidence for the powerful facilitative effect of mnemonic strategy use. (p. 219)

Both of these researches utilised similar principles to the technique used in this study.

In research into the use of mental rehearsal on increases in musical performance, Theiler and Lippman (1995) concluded “… that mental practice may facilitate cognitive coding and help to create optimal levels of attentional focus and arousal” (p. 329). In other words, mental skills involving increased focus and visualisation increased the performance of learning musical pieces significantly. They give several hypotheses in explanation, and quote the work of many others. Importantly, they reported that the use of certain mental techniques improved learning.

The relationship between practice and performance also was supported by Ericsson and Lehmann (1996), who stated that

> Expert performance in domains such as chess, dancing, sports, computer programming, music, and medicine can be accomplished only after about 10 years of intense, daily practice. This high level performance is not simply achieved through talent or by the possession of certain anatomical and physiological traits. Expert performance is moderated by cognitive

> and perceptual motor skills and maximal adaptations. Specific memory skills are used to expand the expert's domain further and continually improve performance. (p. 273)

If memory skills are a predicate to expert performance in these diverse areas, it is reasonable to postulate that memory performance is generally a predicate to higher cognitive functions too. Indeed, Rupp (1998, pp. 252-255) reported research supporting the contention that cognitive skills deteriorate if not used, and that people with mind-active hobbies (e.g., hobbies such as the solving of crosswords or playing games such as chess) scored better on cognitive tests than their less challenged peers. It is my assertion that if cognitive skills 'fade' when not used, then perhaps 'exercise' will improve them. Scruggs and Mastropieri (1991, p. 219) stated that "it also has been shown that mnemonic instruction can be used to learn abstract as well as concrete information, and that it has a facilitative effect on comprehensive and recall". This is further supported by Mastropieri, Scruggs, and Fulk (1990) and Scruggs, Mastropieri, McLoone, Levin, and Morrison (1987). There is therefore support for the proposition that teaching memory enhancement techniques might lead to improved abilities in higher cognitive skills.

Buzan and Keene (1994, p. 49) outlined the "secrets" of a good memory technique as being: synaesthesia and sensuality (using all senses), movement, association, sexuality, humour, imagination, number, symbolism, colour, order/sequence, positivity, and exaggeration. Furst and Furst (1962, Book 1: pp. 6-27) gave three 'tricks' for improving memory recall (of, for example, names) – exaggeration, motion, and unusual combinations. Simpson (2001) reported that the factors promoting good recall are active listening (paying attention), good imagination (to create vivid or ridiculous images), visualisation (using all senses), concentration, a positive attitude, repetition and relaxation.

In relation to her view of what would constitute a successful memory enhancement technique to be applied to mathematics education, Jones (1995, p. 2) stated that according to research, there are three main components to be considered in memory enhancement techniques: teach to all sensory modalities, information is remembered best if it is interesting or useful, and new information is easier to remember if it can be linked to something already stored in the memory bank.

2.5.2 For Memory Pegs

There are many examples in the general literature citing memory techniques for assisting recall that utilise the general principles of the one used in this study. Santos (2006) outlines a number of “memory tricks” including a mention of using memory pegs to attach information that it is desired to recall to information already learned. Pratt (1997) created a list of memory pegs based around the periodic table of the elements as an aid to recalling the elements names.

Capelli (2006) outlines a system of memory pegs different to the ones used in this study, but describes the same technique. He credits the ancient Romans with having developed the system, but mentions their use by modern educators such as Dale Carnegie and memory master Harry Lorayne. Capelli’s system seems to lack the characteristic of the system used by this study in being able to generate unlimited words to attach to numbers, but is a little simpler in that the ‘picture’ associated with a number is in itself the number, thus 2 becomes ‘swan’ and 5 is ‘fish hook’. His system has only 10 pegs, which this author has found sufficient for most purposes, but the memory technique used in this study can have as many numbered pegs as one is willing to learn.

Shouldice (2006) outlines a similar system of memory pegs and describes their use. Jose (2000) outlines an list of memory pegs based upon the alphabet A-Z rather than numbers, and describes a very similar technique for attaching objects to the pegs as that used in this study, The system he outlines is also limited in having only 26 pegs, no method for creating new ones, and no obvious sequence (unless one knows one’s alphabet very well) to match the chosen system’s numbering.

The chosen technique uses numbered pegs, with a phonetic sound associated with each peg. It has been described by Heibloem (1990) and Furst and Furst (1962). The sounds associated with the first 10 pegs are used to construct pegs for numbers 11 and

2.6 How the Memory Pegs Are Used

2.6.1 Learning the Memory Pegs

Initially it is necessary to learn the memory pegs. Each peg has a visual and sensory-rich cue associated with it. For example, the peg for two is Noah. When learning the pegs, the student is encouraged to strongly associate the concept of Noah with two, using a sensory-rich visualisation. Thus the student may imagine Noah taking two animals on to the ark, and imagine the sights, smells, tastes, sounds, and so forth associated with that event. Personal experience indicates that a typical person needs to spend a few minutes making these associations initially, and then revise them once or twice to firmly embed them for future recall. I personally was taught this technique in 1985 and can still recall all 40 pegs that I learnt at that time, despite long periods during subsequent years in which I did not use them. Refer to Appendix A for a transcription of the associations with each peg, and to Appendix B for a list of pegs.

2.6.2 Memorising Lists

The pegs, once learnt, provide a framework for attaching the objects of a list. For example, one may wish to recall a shopping list such as banana, rice, milk, and bread. One actively constructs a visualisation associating each object with a peg in turn. In this example, one would associate banana with ‘tea’, rice with ‘Noah’, milk with ‘may’ and bread with ‘ray’. Tea, Noah, May and Ray are the first four pegs – refer to Appendices A and B for specific details of these and the others.

To continue the example, associating rice with ‘Noah’ may be done by imagining Noah being showered with rice, as in a wedding procession, while walking two animals onto the ark, or perhaps feeding animals rice while on the ark. Personal experience suggests that an amusing juxtaposition is more effective than a bland enactment of a familiar scenario, so the former suggestion, showering with rice (perhaps tons of it) would be more effective for me than Noah feeding animals.

Association of the object to be recalled and the memory peg requires as much or as little time as is necessary to create a sensory-rich visualisation. I have found that the time varies in inverse proportion to the incongruity of the visualisation. In other words, some associations provide more amusing, and hence more memorable visualisations. Associating a hippopotamus with peg number 1 (tea) by visualising a hippopotamus drinking tea is, to me, not as effective as associating peanut paste with peg number 10 (toes) by visualising the obvious connection. The former requires more work and hence more time to make a memorable and amusing connection.

Once the associations are made, the list of remembered objects can be accessed randomly by bringing to mind the peg. Thus in recalling the shopping list item number 2, the peg is Noah, what was Noah doing, Noah was walking onto the ark while being pelted with rice, the item was rice.

It is with a sense of wonderment that persons to whom I have taught this technique realise that somehow the brain / mind does not confuse the lists that one learns. Thus, one does not seem to confuse this shopping list with, for example, the memorised ordered sequence of the parts removed from a motor mower, nor even with last week's shopping list. The brain / mind seems able to keep the contexts separate. The process of how this is achieved would be of interest, but as well as being unknown to this researcher, is beyond the scope of this discussion.

2.6.3 Memorising Numbers

If one wanted to use the memory pegs to recall a number, say the street address of a friend, then one is able to use the memory pegs to create another form of visualisation. For an example, if the street number was 174, we could associate a peg with each number so 174 becomes tea-key-ray which can then be visualised in a sequence of pegs or letters. For a sequential peg use, one could visualise a cup of <u>tea</u> being stirred with a key by some rays of light.. Alternatively a short phrase can be constructed using the peg letters. Since the pegs can mean t, k, and r, one could construct a word such as "teekier" which may be visualised as some sort of rare creature, or as a "taker". Either can be visually associated with the friend. Imagine the friend playing games with the "teekier", or if the friend is one that often takes your things then the association with "taker" would be quite effective. Note that in the privacy of our own minds there is no need to restrict ourselves to imagining only real situations or animals, the technique works as long as the association is good, and memorable.

2.6.4 Using the Memory Peg Principles

More important to this research than using the memory pegs to memorise lists of objects or numbers is the principles behind their use, which include visualisation and association using sensory-rich imagination. To apply this to a general classroom situation, consider learning the historical fact of Lieutenant Cook arriving on the east coast of Australia in 1770. (Cook did not achieve the rank of Captain until after his return from Australia.)

Imagine the scene shown in Figure 10, which roughly represents a man wearing a cook's hat and lieutenants epaulettes arriving at the east coast of Australia in "1770" instead of a boat. Although this is not a sensory-rich visualisation, as one needs to add the other senses, it illustrates how the memory peg principles can be used to memorise factual material that does not consist of a list or numbers.

Figure 10: The Lieutenant cook arriving at the east coast in 1770

2.7 Summary

From this review of the literature, and the previous discussion of barriers to the learning process (see section 2.4), I conclude that an effective memory-enhancing system needs to:

- be sensory and emotionally rich (see section 2.4.1, Philosophical considerations of the nature of reality), including all senses, including sights, sounds, smells, tastes, feelings of hot/cold, texture, and colour
- involve imagination, creativity, and unusual combinations leading to amusing juxtapositions
- involve movement and action
- focus the learner's attention on the task at hand (see section 2.4.2, Factors affecting sensory reception)
- not be dependent on any physical factors (see section 2.4.3, Physical effectiveness of the senses)
- reduce the risk of the learner misrepresenting perceived concepts due to firmly held misconceptions (see section 2.4.4, Factors affecting sensory perception)
- be fun, or humorous, maintain attention, and be easy to learn and use, so that all students can master it, and affirming of the student's ability to learn (see section 2.4.5, Factors affecting learning)
- facilitate concise memory formation, and easy establishment of long-term memory (see section 2.4.7, Factors affecting the correct formation of memory)
- provide self-confidence in one's ability to recall and learn. (see section 2.4.8, Factors affecting the correct recall of memorised material)

The technique chosen for this study is one which either specifically incorporates all or most of these aspects or at least permits their use.

3 RESEARCH METHOD

3.1 Overview of Chapter

This chapter outlines and justifies different aspects of the research method used in this study, and is organised under the following headings:

- Research Design (Section 3.2) which gives a brief overview of the research
- Research Questions (Section 3.3) which outline the research questions and justifies and explains each one
- Study Sample (Section 3.4) which outlines the participants
- Sampling Procedures (Section 3.5) which describes how the participants were chosen, and the restrictions placed upon that choice
- The Intervention (Section 3.7) which outlines the actual training program
- Data Sources (Section 3.8) which describes the data collected in the study
- The computer program written to administer the TOSRA test (Section 3.9)
- Data Analysis Procedures (Section 3.10) which outlines the analysis procedures used on the data, and the equations used in calculations

3.2 Research Design

Essentially the research encompassed a quasi -experimental design, namely a one group pre-test - post-test design with a control group, where the experimental group undergoes an intervention, in this case the memory peg technique (see for example, Cohen, Manion & Morrison, 2000).

In the following discussion, aspects of the research design are outlined with respect to the characteristics of good research design proposed in the December 2003 version of a manual produced by the U.S. Department of Education (see reference under the National Center for Education Evaluation and Regional Assistance 2003, hereafter NCEERA).

3.2.1 The Intervention

NCEERA (2003, page 5) required that a good research paper outline certain specific details of the intervention. The intervention used in this study was administered by this researcher, who in the late 1980s conducted workshops in mind dynamics for a commercial operation, a small part of which included teaching the memory enhancement technique used in this study to adults. The researcher at the time of the study was a practicing teacher, and Head of Curriculum, in a small private school in Queensland, Australia. The selection of the control and test groups is outlined later (section 3.5) as is the nature of the intervention itself in (section 3.7).

3.2.2 Random Assignment

NCEERA (2003, page 5) stated that good research design involves processes that randomly assign subjects to the test and control group. The nature of this study involved a volunteer test group. By its very nature, this tended to be students who desired better academic results and were attracted by the description of the benefits of the technique purported by the researcher during the advertising phase of setting up the test group (discussed under section 3.5.1). As discussed under section 3.5, the entire eligible population was involved as either test group or control group. Data were collected on both groups in a pre- and post- intervention analysis, which design permitted some confidence that an analysis could be performed comparing the two groups statistically and therefore identify any significant difference between the two groups. It was intended that differences between the two groups resultant from the inclusion into the test group on a volunteer basis would thus be identified during analysis should it occur. This satisfies the NCEERA (2003, page 6) requirement that the study identify any differences between the test and control group prior to the intervention.

3.2.3 Valid Outcome Measures

NCEERA (2003, page 6) required that outcomes should be measured using valid real-world assessments and any self-reported outcomes should be validated by independent or objective means. Since the stated purpose of this research was to investigate the purported effects of a training technique upon student academic performance, it was necessary to have a pre- and post- intervention measure of that academic performance upon which a statistical analysis could be performed. This was completed by collecting and averaging school subject assessments results from the students' school report cards for three terms prior to and three terms subsequent to the intervention. The author acknowledges the difficulties associated with attempting to quantitatively measure changes to academic achievement, there being in existence so many factors to monitor and attempt to control. In this study it is assumed that the analytical comparisons made between the test and the control groups limits, while not necessarily avoiding, the impact of these assorted other factors. The problem of ensuring that any observed change in assessments was due solely to the intervention was further compounded by the limited sample size, discussed later under "Study Sample" (section 3.4).

In recording the test group self-reported data on one of the research questions (question 4, see section 3.3.4), the author acknowledges that there was no possible method of validating the data by independent objective measures and therefore the data collected for this analysis has this limitation of reliability and should not be used without acknowledgement of this concern.

NCEERA (2003, page 7) required that data on all members of the intervention group of a randomly sampled population should be included in reporting the study. This aspect is discussed in sections 3.4 and 3.5 later.

3.2.4 Statistical Analyses

NCEERA (2003, page 8-10) outlined procedures for determining whether a study has sufficient statistical rigour to allow conclusions to be thought of as 'strong evidence' in support of the effectiveness of the intervention. The data in this study has been subjected to statistical analyses using Student's t-score analysis on independent groups, and all analyses have been reported.

It is acknowledged from the outset that any data collected as a part of this initial small-scale study should not be interpreted as anything other than an indication towards possible effects, leading to recommendations to further study or research. It was not intended that this one piece of research should establish a firm and sound basis for asserting the existence of direct causality between learning a memory training technique and increased academic performance. The author acknowledges that an assertion such as this needs to result from a much larger and more long-term trial and study than that envisaged in this research. However, this study was intended to open a new area of interest, and the data and analysis may be taken to indicate whether further efforts by other researchers are warranted.

3.3 Research Questions

This section briefly summarises how each of the four research questions were tested.

3.3.1 Question 1 – Effect on Assessments

> Does learning of a memory enhancement technique lead to a significant increase in a student's results in assessments in science and mathematics in either of the two facets of assessment, recall and complex reasoning?

This question addresses the core premise of the discussion in the literature review – that practicing a technique for improving recall ability could lead to improved performance both on the recall sections of normal school assessment and on the assessment of higher cognitive functions.

To test this question, the assessment results of the test group and control group were recorded for three school terms (approximately 9 months) prior to, and for four successive terms after the training session. The results on assessments for the term immediately following the intervention were not included in the analyses as it was assumed that these may be transitory in nature, that is, that should a significant increase in ability have occurred, this would not have been as obvious in the assessments which occurred a few weeks after the training session, since the intervention occurred in the middle of a unit of work. By treating this term's results as transitory, comparisons could be made between the students' pre-existing academic achievements, as indicated by the mean of their results on the preceding three assessments, and their academic achievements post-intervention, as indicated by the mean of the results on three complete units of work following the intervention.

Taking the assessment results of three units of work reduced the impact of student preferences for the changing strands of work completed in those units. In both mathematics and science, each term's work is chosen from different strands in those subjects. Thus, science units of work vary from chemistry to physics to biological science and earth science from term to term, and sometimes within terms. In mathematics, strands are usually changed twice during a term – for example trigonometry and algebra may be covered in one term. The assessment criteria of recall and complex reasoning are usually measured as part of the assessment in all units of science and mathematics in Queensland, and this was the situation during the units which occurred during the course of the research.

The problem that might have arisen if only one term of work prior to and after the intervention had been used is that, in the experience of this researcher, students typically do better at some strands than at others, and this would have introduced an unacceptable bias and uncertainty into the data. By using three terms of work prior to and after the intervention it was assured that at least two-thirds of the strands were repeated in each subject in each year level – that is, that the students completed at least one unit of work from each of two-thirds of the strands both before and after the intervention. It was also felt that by sampling the wider range of results provided by three terms of work, and analysing the mean of these three terms, the effect of student preference for particular strands could be minimised. Taking more than three terms proved problematical as it reduced the number of students available for the control and test group, due to the variable enrolment, as is discussed later.

3.3.2 Question 2 – Effect on Attitude

> Does the learning of a memory enhancement technique lead to a significant change in attitude towards science?

There was a postulated subsequent link between students' perceptions of science and their learning of the memory enhancement technique. If the students were to improve their performance on their assessments, this may have led to a change in attitude towards science, scientists, and science careers. It was decided to monitor for changes in these attitudes by using a test of science attitudes prior to and some time after the intervention.

Both the test group and some of the control group were administered the Test of Science Related Attitudes (TOSRA) (Fraser, 1981) prior to the intervention, and again approximately nine moths after the intervention. Details of the TOSRA test with scales and representative items from each scale are shown in section 3.8.2 and the full list of statements, their scale, and scores is given in Appendix C.

The test was administered by using a computer program specially written for the purpose, (see section 3.9) which also had the desirable effect of removing the possibility of transcription and scoring errors when processing the data, since the program calculated the scores automatically. Students were given a copy of the program on floppy disk to complete during their own time, and given the opportunity of using a school computer if needed. It was explained to the students that there was no correct answer to the questions so they should complete the questionnaire truthfully, and this advice was also provided at the introduction screen of the computer program.

This research question was then tested by comparing the test groups' and control groups' changes in scores on the TOSRA tests using independent t-test analysis.

3.3.3 Question 3 – Memory Test Recall

> Does the learning of a memory enhancement technique lead to a significant improvement in the ability to recall lists of unrelated objects?

The memory training technique chosen for the study, which is described in detail in section 3.8.4, is one specifically for the memorisation of lists of objects. As discussed in the literature review chapter, improving recall in this way may have led to improved recall ability in other areas through transference of the skills involved. This secondary question was posed to test the validity of the assumption and assertion that the memory technique does actually lead to an improved ability to recall lists of objects. Should this have not been the case, the proposition that practice of this technique could lead to improved recall ability in other areas would have been rendered highly questionable and the implications for complex reasoning would have been rendered irrelevant.

During an introductory presentation, students, from whom the test group later volunteered, were invited to test their memory. Although this test data were not recorded nor used in the study, there was no apparent aptitude demonstrated by the students to indicate that any of them had memory abilities above what was normal for that age group.

The test group completed a memory test comprising the memorisation of a list of unrelated objects as part of the training sessions. The test group and some of the control group completed a similar test nine months later, allowing for a comparison between the trained and untrained participants.

3.3.4 Question 4 – Memory Test Practice

> Does the amount of time spent practicing a memory enhancement technique improve performance on a test of recall?

Assuming that the previous questions lead to a conclusion that practicing a memory enhancement technique does lead to improved test scores, a further question of whether the amount of time spent practicing is important becomes relevant. Specifically, is there an optimal amount of time spent practicing, or is there a clear trend that more time spent practicing leads to better performance (as one would be tempted to assume)?

Students in the test group recorded the amount of time they spent practicing the technique in the weeks following the training session, so that a comparison between their subsequent performance and the practice time could be made.

It should be noted that since the students recorded and reported the time spent practicing, without independent monitoring or validation checks being in place, the results as recorded are without doubt highly suspect. It is quite likely that students did not accurately report the time spent practicing. With this in mind, students were asked to report to the nearest 10 minutes. The results should be viewed as being unreliable in exactitude, but valid in generality.

3.4 Study Sample

The test and control group was chosen from Queensland high school students (school Years 8 to 12 inclusive, ages from 13 to 17 years) who were enrolled at a small, private, co-educational, independent, international college in a semi-rural area to the south of Brisbane during the period of the study, from April 2002 through to November 2003, a total of 19 months. All students who were not part of the test group, and who met the sampling restrictions discussed below, became part of the control group.

Twenty students were used as the test group. Nine other students were used as a control group for the purposes of comparing TOSRA scores and memory test scores, and a additional 30 students were included in the control group to provide comparability with respect to classroom assessment results. These 59 students in total comprised the entire student population of the chosen school that satisfied the restrictions placed upon the participants by the research design factors, which are discussed later under Restrictions (Section 3.5.4).

3.5 Sampling Procedures

3.5.1 Test Group

Test participants were volunteers, who responded to a leaflet distributed to all students in the selected high school. The leaflet outlined the nature of the research project and offered memory enhancement training. Parental permission was received for all participants. The entire test group studied science and mathematics for the duration of the period in question. Non-English speaking background students were not included in the analysis for reasons mentioned under 'Restrictions' below. The numbers of males and females from each age group that participated in the test group are recorded in Table 1.

Table 1: Number of participants by Year level and gender

	Test			Control			Total		
Year	Male	Female	Total	Male	Female	Total	Male	Female	Total
8	3	1	4	4	3	7	7	4	11
9	3	0	3	0	3	3	3	3	6
10	3	0	3	3	7	10	6	7	13
11	7	0	7	7	7	14	14	7	21
12	2	1	3	2	3	5	4	4	8
Total	18	2	20	16	23	39	34	25	59

3.5.2 Control Group

Control group students were all other students at the school who

- were present for the entire period from term 2, 2002 to term 4, 2003, and
- were not from non-English speaking backgrounds, and
- studied at least one science and / or mathematics subject.

The academic results of the entire control group were obtained from school records. Control group students were asked to volunteer to take the TOSRA test and a memory test, without attending the training. A limited number (9) did so, but this was felt sufficient for comparison purposes, as there are other indicators from sources outside this study to validate the observed results, as is discussed later.

The numbers of males and females from each age group that were included in the control group are recorded in Table 1.

3.5.3 Demographics of Test and Control Groups

All participants were Australian nationals and native English speakers. The number of participants in the test and control groups, by Year level and sex are given above in Table 1. The Year level reported was at the time of the initial training session, that is, the 26th February, 2003.

3.5.4 Restrictions

Students from non-English speaking backgrounds (NESB) were not included in the test group data or in the control group. In part, this was due to the English-language-intensive nature of the training program. It is also this researcher's experience that there is usually a significant increase in assessment results recorded by overseas students as their English-language ability improves, over a period of one to two years after commencing studies in Australia. Nevertheless for equity purposes, NESB students were given the opportunity to take part, but their results have not been included in the analyses, as any improved academic result may have primarily been due to be a result of their increased English language proficiency. Inclusion of their results may have introduced an unacceptable bias into the research results.

Since the target school was small (less than 100 students in total in Years 8-12), students from several Year levels were included in the test group. The school also had, during the period of the study, an unstable population in that many students were not enrolled for the full period of time used to gather assessment data (seven terms, or almost two Years). Data concerning students who were not present for the entire time period were not included in the control or test group.

All students from Years 8 to 10 inclusive who were present, but did not volunteer to be included in the test group, have been used as a control group for the gathering of academic data. Students from Year 11 and 12 were not included in the control group if they did not study a science subject, but all others were. The entire test group in Year 11 and 12 studied a science subject. At the target school, all students in Year 11 and 12 study a mathematics subject.

Those students listed as "Year 11" at the time of the study have a discrepancy in their subjects in that they changed from Year 10 subjects in 2002 to Year 11 subjects in 2003. Traditionally, in this researcher's experience, students moving from Year 10 to Year 11 tend to have a significant drop in assessment results, probably due to the increased workload. Since the test group is being compared to a control group of similar age and subjects, this change of subject should not have unduly influenced the results nor invalidated the comparison between the test and control groups, as the postulated effect affects both the test and control groups..

3.6 The Memory Training Technique

The chosen technique is referred to as "Memory Pegs" by Heibloem (1990) and as the "Memory Cloakroom" by Furst and Furst (1962). The 'pegs' are also referred to by Strydom & Du Plessis (2005, p. 2) as "number-sound mnemonics". Both Heibloem and Furst and Furst claimed that the technique has existed for thousands of years, although neither listed a source for this information. Heibloem (1990, p. 54) reported that the University of Cologne found that "if a person spent five minutes a day practising this technique [memory pegs], he could double the effectiveness of his memory in just 30 days". The training technique is fully described in "APPENDIX A : Transcript of Teaching Technique".

3.7 The Intervention

The test group were trained during 'Activities', which is the target school's sports afternoon. They were required to attend two sessions of training at the start of the research and a further session nine months later.

The first session of the training program introduced and provided instruction in the memory technique. A transcript of this training session is included in Appendix A. During this session, the students learned the principle of the memory pegs and how to use them to improve recall of lists of objects.

The second training session was a brief revision of the memory pegs that took approximately ten minutes. The purpose of the second session was to ensure that the entire test group had successfully memorised the pegs during the preceding session and give brief description on how to use the principles of the technique to memorise other things. The method for memorising facts was described in chapter 2.

The final session that occurred nine months later was used to administer the final memory test. Nine months was chosen firstly as it coincided with the completion of the assessment data gathering period, and secondly as it was believed that recalling a list of unrelated and irrelevant objects after this lengthy period of time would be a true indication of the effectiveness of the technique. Some volunteers from the control group also took part in a memory test at the time of the final session, wherein they had to recall the same information after a much lesser period of time..

3.8 Data Sources

3.8.1 Pre- and Post- Assessment Tests

To validate the effect on the various cognitive aspects, the students' results were collected in the two broad main areas of school science and mathematics examinations – "recall and simple application", and "processing skills and complex problem solving skills" as outlined for example in the Queensland Studies Authority

Senior Syllabi in the sciences (e.g Board of Senior Secondary School Studies Senior Chemistry Syllabus 1994). The results from the three preceding terms and the three subsequent terms were collected. This spread of available assessment data is illustrated in Figure 11.

Year	2002			2003			
Term	2	3	4	1	2	3	4
Detail	✓	✓	✓	Initial Training ✓	✓	✓	Final tests ✓

Figure 11: Spread of data available with respect to school term examination results

This study acknowledges that recall performance assessment and the assessment of higher cognitive function are areas in which much research has been conducted, but for the purposes of this study, an analysis of pre- and post-training achievement on the participants' normal assessment program was considered sufficient. These assessments were considered to provide a more relevant data set, being directly related to school achievement rather than to an artificial measure that might or might not be a predictor of school achievement.

At the time of the research, assessment in the Queensland school system, in science and mathematics, was by use of a standards criteria schema. Student achievement was judged against a scale of indicators (called objectives), and results awarded in several criteria.

Tests in both subjects consist of three sections, each containing an assortment of question types. The nature and proportion of question types was that typically used in Queensland school examinations. Two of the three sections require some degree of recall, and these have been combined and recorded as a 'knowledge' assessment. In science these were "Knowledge of Content" and "Scientific Processes", and in mathematics they were "Recall" and "Simple Application". The third section assesses a student's problem solving and complex reasoning skill, a higher order cognitive function, and this has been recorded as a 'process' assessment. It was considered that grouping into these two categories would allow the analysis of whether the test group improved their retention abilities (knowledge) and whether there was a flow on to the higher cognitive functions (process). Table 2 lists some typical question types assessing these criteria. In Queensland, the teachers within a school write all such tests, so these should be considered examples only, and have been taken from tests written by the author. A sample of two complete examination papers is given in Appendix D.

Table 2 : Sample questions illustrating typical question types

Knowledge	Recall	Year 10 Science : What does chlorophyll do in a plant ?
		Year 8 Mathematics What is the total of the angles in a triangle ?
	Application / Processes	Year 10 Science: If a car travels 80 km in 1 hour, what is its velocity?
Process	Complex Reasoning	Year 11 Chemistry : Silicon trisulphide (SiS_3) probably does not exist, but if it did, what shape would the molecules be?

Results in both science and mathematics were recorded. Hereafter, these result categories are abbreviated in tables as per the key in Table 3.

Table 3 : Abbreviation of Assessment criteria

Subject	Criteria	Abbreviation
Science	Knowledge	Sc_Know
	Processes	Sc_Proc
Mathematics	Knowledge	Ma_Know
	Processes	Ma_Proc

3.8.2 TOSRA

The test group and volunteers from the control group were administered the Test of Science Related Attitudes (TOSRA), (Fraser, 1981). After approximately 36 weeks, the students repeated the TOSRA tests.

The TOSRA test developed by Fraser (1981) was designed to provide a measure of students' attitudes to science, measured using seven scales. In this study it has been used to determine whether the training program led to any significant attitudinal changes in the test group, compared to the control group. The total scales and scoring system are described in *Table 4* and Table 5. All of the items in the TOSRA test, and their scoring values, are listed in Appendix C.

Table 4: The TOSRA scales and a representative item

Scale	Example of Item
Social Implications of Science	Money spent on science is well worth spending. (+)
Normality of Scientists	Scientists usually like to go to their laboratories when they have a day off. (-)
Attitude to Scientific Inquiry	I would prefer to find out why something happens by doing an experiment than by being told. (+)
Adoption of Scientific Attitudes	I enjoy reading about things which disagree with my previous ideas. (+)
Enjoyment of Science Lessons	Science lessons are fun. (+)
Leisure Interest in Science	I would like to belong to a science club. (+)
Career interest in Science.	I would dislike being a scientist after I leave school. (-)

Participants indicate whether they strongly agree, agree, are unsure, disagree, or strongly disagree with each of 70 statements. The responses are scored as given in Table 5. Some items, designated '+' are scored positively, meaning that a strongly agree gets the highest score of 5 and that strongly disagree gets the lowest score of 1, and some, designated '-' are scored negatively, meaning that strongly disagree gets the highest score of 5 and strongly agree gets the lowest score of 1. This reflects that the test contains a mixture of statements with positive attitudes and negative attitudes towards the various aspects of science.

Table 5: Scoring the TOSRA test

+ or - item	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
+	5	4	3	2	1
-	1	2	3	4	5

The test was administered by giving the students a computer disk containing a specially written computer program as described in section 3.9. The program had students click on one of five buttons indicating “strongly agree” through to “strongly disagree” in response to a displayed statement related to attitudes about science. The program recorded individual responses to questions as well as calculating the totals for each scale of the test.

3.8.3 Practice Time

The amount of time, in rounded off 10-minute blocks, that each participant spent each week practicing the memory training technique was recorded. This amount of time was estimated and supplied by the students, and, unfortunately, should not be considered rigorously provided by the students. It is quite likely that some students over-estimated or over-reported the time spent, and that some students underestimated or under-reported the time spent.

3.8.4 Memory Test

During the intervention, the test group was given a list of objects to recall as part of the training process, and as part of the training were also given an informal test of recalling these objects. Prior to the training, the test group did not demonstrate any significant ability to recall the list of objects. This test was performed to assess the effectiveness of the chosen memory technique in actually achieving the result of improving the ability to recall lists of objects, prior to analysis of the effect of having learned such a technique upon academic achievement. The fully correct response to the memory test is given in Table 6. The memory test consists of the recall of the ten memory pegs and the ten objects originally learned. It is this researcher’s personal experience with training adults with this technique that the original list can be recalled with relative ease many years after the training.

The nine months represented the time between the intervention and the collection of the last term’s assessment data used in the study. It was also felt that this amount of time was adequate to ensure that the list of unrelated and irrelevant items would have been forgotten had the technique had no effect on the students’ ability to recall.

Table 6: The memory test

Number	Peg	Object to Recall
1	tea	hippopotamus
2	Noah	motorbike
3	may	rat-traps
4	ray	worm
5	law	banana
6	jaw	double-decker bus
7	key	submarine
8	fee	snake
9	pea	television set
10	toes	peanut paste

The final test, which occurred some months after the intervention, was a test in which students were asked to recall the memory pegs and then the object list. After an initial attempt, the test group students were provided with assistance recalling the memory pegs, and then given another opportunity to recall the objects. Additional marks were given only to successful recall of the objects, not the pegs, on the second try. This second opportunity was provided as it is this researchers personal experience that the technique allows for correct recall of the object provided that the peg is recalled first. The results from the two opportunities to recall the objects were recorded separately. Participants were asked to complete a blank two-column, ten-row table with the list of pegs and the list of objects (see Figure 12 for an example of a test scoring 11 points). They were then given clues about the pegs, and permitted another attempt at the objects, for the second try. They were scored one point for a correct placement of the object or peg with the correct number, and a half point for a correct peg or object in the wrong number. At the second try, only the placement of the objects was scored for additional credit.

A small proportion of the control group volunteered to memorise the 10 memory pegs and the list of 10 objects as 20 unrelated objects (presented as two columns of 10), but without explanation or training in their use, that is, they were asked to memorise 20 unrelated objects.

The test group and the control group had different periods of time with respect to the memory test. The test group were required to remember the list for a period of nine months following the training session. The control group were given the list and asked to recall it approximately a week later. This should have resulted in a benefit leading to increased performance for the control group, as they did not have time to 'forget' the list.

Number	Memory Peg		Object to Recall	
1	Tea	✓		
2	Noah	✓	motorbike	✓
3	May	✓	Rat traps	✓
4	Ray	✓	banana	½
5				
6	Jaw	✓		
7	Key	✓	yellow submarine	✓
8	bay	½		
9				
10	Toes	✓	Peanut paste	✓

Figure 12 : A sample memory test answer grid

3.9 Computer Program

The author wrote a computer program to assist with the data collection and analysis, using a combination of Borland Delphi® language (version 2) and the Borland Database Desktop® programming environments. The Borland Delphi language uses an interactive visual design environment for the production of on-screen elements, and allows programming in a high level language (a descendent of the Pascal programming language) for the non-visual elements such as data processing. The Borland Database Desktop allows quick construction of databases, which was used to collect all student data into a single file for ease of processing. The program written in Delphi accessed the database that was created by the Database Desktop to perform various programmed analyses.

The program consisted of three sections, accessible through password-protected menu selections. The first administered the TOSRA test by collecting student's responses to the items that were presented on-screen, both prior to the intervention and at the end of the research, and also collected demographical information and information about the times spent practicing. A copy of the program was placed on to a floppy disk and given to the student who then completed the questionnaire and entered the other information. This information was saved in an encrypted data file on the disk. The disk was collected and held by the researcher until the final TOSRA test, when it was again loaned to the student. A copy of the data was retained in case of accidental loss or erasure. Following completion of the final data entry, the data were then retrieved from the disk using the computer program and merged with the other student data into a single database.

The second section of the program was used by the author to input student assessment results and the results of the memory test. The author also inputted the data for those of the control group who did not complete the TOSRA test. Following this data input, a subroutine of the program was used to randomly assign code names and convert dates of birth into ages to disguise the identity of the participants. The program generated an encrypted file cross referencing the original and code names that allowed the researcher to re-identify the participant should that have become necessary for data validation.

The third section of the program collated the collected information, calculated means, standard deviations, and t-scores and output these results into a tab-delimited text file from which the data were copied and inserted into this thesis and converted to Microsoft Word® format tables and charts.

The program used a standard Microsoft Windows® visual interface that allowed the students, who were all familiar with this style of program from their compulsory school computer studies, to input their information with minimum prior training, although a help system and on-screen tips were encoded and available should they have needed assistance. All students reported that using the program presented no difficulties to them, and all successfully inputted their information. Students were allowed to encrypt their data files with their own password (which could be overridden by the program held by the researcher) and one student reported difficulty in having forgotten the password, having completed only half the questionnaire and not been able to re-enter the program to complete it. That student on his own initiative re-completed the entire questionnaire and the researcher discarded the incomplete version.

3.10 Data Analysis Procedures

3.10.1 Confidentiality

This section outlines how participant confidentiality has been achieved.

3.10.1.1 Name Codes

In order to preserve anonymity, student names have not been recorded in this thesis. Instead, students have been randomly allocated a code that has been used throughout, which has been allocated by this process:

- Test group participants were randomly arranged in sequence, and then allocated a code starting with TG- (for "Test Group") followed by a sequentially allocated number from 1 to 20.
- Control group participants were randomly arranged in sequence, and then allocated a code starting with CG- (for "Control Group") followed by a sequentially allocated number from 1 to 39.

Thus TG-4 is a member of the test group and CG-6 is a member of the control group, the number being a random designation.

3.10.1.2 Dates of Birth

Since there was a small population drawn from, the dates of birth could have been used to identify the participants, so only ages have been recorded. The recorded age was calculated for all participants at a particular date during the study, and is expressed as years and months. Since this date was selected randomly in a period of almost two years and has been kept secret, the anonymity of the participants has been somewhat protected. Care was taken to not use the ages as an absolute value indicative of a particular physical age. The year of schooling was consider a more relevant basis on which to analyse data, as the students within a particular year were experiencing similar educational processes, whereas students of the same age were perhaps not, should they have been in different year levels.

3.10.1.3 Year and Gender

There were sufficient persons involved that it was not necessary to disguise the gender and year level of the participants. There remained a risk that members of the test group would be able to identify some individuals from their knowledge of who was present during the training session, but no alternative was available given the small test group size. Additionally, all of the test group were already aware of who had taken part in the study.

3.10.2 Collected Data

The data collected during the study consists of :

- examination results (in science and mathematics) in each of two criteria, expressed on a 15 point scale, that is A to E, with + & - modifier
  - of three term sets before the training program (see Figure 11)
  - of three term sets after the training program
  - of similar examination results of a matched control group from the same classes

for all of the test group and all of the control group

- examination results from other subject areas were briefly and non-rigorously analysed for significant changes not evident in the science and mathematics results
- pre- and post- attitude test results, as assessed with the TOSRA instrument for all of the test group and some of the control group
- a final test of recall for all of the test group and some of the control group.

- data concerning the amount of time that members of the test group spent practicing. However although the expectation was that the students should practice the technique for at least 10 weeks, the test group participants failed to maintain a substantial practice regimen after the first few weeks.

Demographic data on the students' year level and gender were also noted and are recorded in Table 1: Number of participants by Year level and .

The data were recorded in a specially written database programmed in Borland© Delphi© by the author, a description of which was included earlier in section 3.9. This provided more flexibility and greater ease for the researcher in analysing the multi-dimensional array of data for trends than available commercial databases.

3.10.3 Analyses Performed

Comparisons between mean and standard deviation data were made on:

- test group versus control group assessments for three terms prior and four terms after intervention
- test group versus control group average assessments for three terms prior and three terms after intervention
- test group results on a "Test of Science Related Attitudes" (TOSRA) before and after intervention (9 months later)
- test group versus control group results on the TOSRA test
- test group records of time spent practicing the memory technique versus their assessment results
- test group versus control group results on the memory test.

To test whether the difference between the means and standard deviations of the test and control groups were significant, Student's t analysis, where

$$t = \frac{\left| mean_1 - mean_2 \right|}{\sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

was used (derived from Lennox and Chadwick, 1970, p411).. This method has been used for quantitative analysis for many decades for comparing the means of independent samples.

The value of t, with ($n_1 + n_2 – 2$) degrees of freedom is compared to a table to find the degree of confidence, which in this study indicated the probability that the test group and control group were of the same population. A level of 5%, meaning that there would only be a 5% probability that the two samples represented the same population, was chosen as a suitable degree of confidence in order to test the significance of the results.

Within the test and control groups, some school year level comparisons were also made.

4 ANALYSIS AND RESULTS

4.1 Overview of Chapter

This chapter reports and briefly discusses the data collected and analysed during the course of this study. These data are discussed under the headings related to the research question they attempt to answer:

- Research Question 1 comparing the assessment results of the test and control groups (Section 4.2), in which the means and standard deviations of the students' results on assessments in four criteria are compared and analysed for significant differences.
- Research Question 2 comparing the TOSRA scores of the test and control groups (Section 4.3) for significant changes related to the intervention.
- Research Question 3 testing whether the memory enhancement technique lead to a significant improvement in the ability to memorise lists (Section 4.4).
- Research Question 4 assessing whether the time spent practicing the technique by members of the control group led to a significant difference in assessment results in any of the four criteria. (Section 4.5).

4.2 Research Question 1

Does learning of a memory enhancement technique lead to a significant increase in a student's results in assessments in science and mathematics in either of the two facets of assessment, recall and complex reasoning?

4.2.1 Trends in Means

It is conceivable that there would be differences in the means of the sample population from term to term as a result of predictable fluctuations in assessment results related to the nature of the different topics and contexts being studied in those terms. That is, it is this researcher's experience that students frequently achieve to a different standard on different contexts or topics within the one subject. However, should the learning of a memory enhancement technique have no effect on student results in assessments in science and mathematics, then it would be expected that there would be no general trend difference in results between the test and control groups.

In order to analyse for a difference in general trend, assessment results for each of the Year levels 8 to 12, for each of the four assessment criteria (mathematical knowledge, mathematical processes, scientific knowledge, and scientific processes – see Table 367 for the abbreviations used for these terms) and each of the seven assessment items (2002 term 2 through to 2003 term 4, inclusive) were recorded. These data have been included in Appendix E, from which means and standard deviations were calculated and are shown in Tables 7 to 11. Also calculated and included in these tables are the differences in means between the test group and the control group for each year level, which allow for a simple but not rigorous comparison of general trend. These differences in mean data are also plotted in Figures 13 to Figure 18: Difference in means (test minus control) of before and after assessment results averaged over three assessment instruments.. In each of these plots of differences in results, the mean of all four assessment criteria is plotted as well, for ease of comparison and to make any qualitative trend in overall results visually apparent. These plots have been drawn to the same scale for ease of comparison.

In each table, the intervention occurred during term 1, 2003, so the 2002 data corresponds to pre-intervention, and the 2003 terms 2 to 4 data represent post-intervention.

Table 7: Descriptive Statistics (Means and Standard Deviations) for Test and Control Groups in Year 8 over seven terms (N = 11)

Assess date		Ma_Know			Ma_Proc			Sc_Know			Sc_Proc		
		Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)
2002 Term 2	Mean S.D.	10.75 (2.05)	11.57 (1.76)	-0.82	10.00 (2.55)	11.29 (3.06)	-1.29	9.00 (1.87)	10.71 (2.60)	-1.71	9.75 (2.68)	9.43 (2.97)	0.32
2002 Term 3	Mean S.D.	11.00 (1.58)	10.86 (1.64)	0.14	10.75 (1.92)	12.14 (1.55)	-1.39	10.00 (2.00)	10.86 (1.25)	-0.86	10.25 (2.86)	9.43 (3.50)	0.82
2002 Term 4	Mean S.D.	10.50 (1.50)	11.57 (2.06)	-1.07	10.25 (1.09)	10.14 (3.14)	0.11	11.75 (1.79)	10.71 (2.60)	1.04	10.25 (2.86)	11.00 (2.27)	-0.75
2003 Term 1	Mean S.D.	11.00 (1.87)	11.14 (2.59)	-0.14	10.00 (0.71)	10.00 (1.31)	0.00	11.00 (2.12)	11.14 (2.23)	-0.14	9.50 (2.06)	9.14 (3.48)	0.36
2003 Term 2	Mean S.D.	10.25 (2.28)	11.00 (2.39)	-0.75	9.50 (1.66)	8.71 (2.19)	0.79	10.50 (2.06)	7.86 (3.31)	2.64	9.25 (2.49)	9.43 (2.32)	-0.18
2003 Term 3	Mean S.D.	10.50 (1.66)	8.71 (3.15)	1.79	9.00 (0.71)	9.86 (3.09)	-0.86	9.75 (1.48)	9.29 (2.91)	0.46	9.25 (1.30)	9.57 (3.89)	-0.32
2003 Term 4	Mean S.D.	10.25 (1.48)	10.57 (2.06)	-0.32	9.00 (1.22)	8.71 (3.73)	0.29	10.50 (2.06)	9.57 (2.97)	0.93	9.25 (2.86)	6.29 (1.48)	2.96

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Table 8: Descriptive Statistics (Means and Standard Deviations) for Test and Control Groups in Year 9 over seven terms (N = 6)

Assess date		Ma_Know			Ma_Proc			Sc_Know			Sc_Proc		
		Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)
2002 Term 2	Mean	11.00	13.00	-2.00	9.67	13.00	-3.33	12.33	12.33	0.00	12.00	13.67	-1.67
	S.D.	0.00	0.82		0.94	1.41		0.94	1.25		2.83	1.25	
2002 Term 3	Mean	10.00	13.00	-3.00	11.33	12.67	-1.33	11.00	13.00	-2.00	11.67	13.67	-2.00
	S.D.	1.41	0.82		2.05	0.94		2.16	1.63		3.30	1.25	
2002 Term 4	Mean	11.33	12.33	-1.00	10.67	11.33	-0.67	11.33	11.67	-0.33	11.67	12.33	-0.67
	S.D.	1.70	1.25		1.70	2.49		2.49	2.49		3.30	1.89	
2003 Term 1	Mean	11.00	11.67	-0.67	8.67	11.33	-2.67	11.67	14.00	-2.33	11.00	12.67	-1.67
	S.D.	0.82	0.94		0.47	0.47		1.25	0.82		2.94	2.05	
2003 Term 2	Mean	11.67	13.00	-1.33	10.33	11.00	-0.67	11.00	11.67	-0.67	10.00	12.67	-2.67
	S.D.	0.47	1.63		1.25	0.82		1.63	0.94		2.94	1.25	
2003 Term 3	Mean	10.67	12.33	-1.67	9.67	11.33	-1.67	10.33	12.33	-2.00	10.33	11.67	-1.33
	S.D.	0.47	1.25		0.47	1.70		0.47	1.25		2.05	1.70	
2003 Term 4	Mean	10.67	12.67	-2.00	10.00	11.33	-1.33	11.00	11.67	-0.67	9.67	10.33	-0.67
	S.D.	0.47	1.25		0.82	1.70		1.63	1.25		1.70	3.30	

Table 9: Descriptive Statistics (Means and Standard Deviations) for Test and Control Groups in Year 10 over seven terms (N = 13)

Assess date		Ma_Know			Ma_Proc			Sc_Know			Sc_Proc		
		Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)
2002 Term 2	Mean S.D.	7.33 2.49)	10.10 2.02)	-2.77	6.00 0.82)	11.50 2.06)	-5.50	8.67 1.70)	10.60 2.94)	-1.93	9.67 1.89)	12.90 2.07)	-3.23
2002 Term 3	Mean S.D.	7.67 0.94)	11.40 2.24)	-3.73	8.67 0.94)	11.20 2.27)	-2.53	7.67 1.25)	9.90 2.02)	-2.23	10.67 3.40)	12.00 2.45)	-1.33
2002 Term 4	Mean S.D.	6.00 2.45)	11.10 3.18)	-5.10	8.33 0.47)	10.90 2.70)	-2.57	8.67 1.25)	12.50 1.57)	-3.83	8.67 2.05)	12.90 1.37)	-4.23
2003 Term 1	Mean S.D.	7.00 1.41)	10.40 3.26)	-3.40	8.67 0.47)	10.40 3.10)	-1.73	7.33 1.89)	11.80 1.40)	-4.47	9.33 2.05)	11.30 2.00)	-1.97
2003 Term 2	Mean S.D.	8.33 0.47)	10.00 1.95)	-1.67	10.33 0.94)	11.50 2.50)	-1.17	8.67 1.25)	11.60 1.56)	-2.93	9.67 2.05)	11.70 1.68)	-2.03
2003 Term 3	Mean S.D.	6.33 2.87)	7.70 2.93)	-1.37	7.33 0.47)	9.80 2.79)	-2.47	8.33 1.25)	11.70 1.73)	-3.37	9.33 1.70)	11.70 1.90)	-2.37
2003 Term 4	Mean S.D.	8.00 1.41)	8.60 2.46)	-0.60	8.33 1.25)	10.30 2.41)	-1.97	8.33 1.25)	11.70 1.73)	-3.37	9.00 1.41)	11.60 1.85)	-2.60

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Table 10: Descriptive Statistics (Means and Standard Deviations) for Test and Control Groups in Year 11 over seven terms (N = 21)

Assess date		Ma_Know			Ma_Proc			Sc_Know			Sc_Proc		
		Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)
2002 Term 2	Mean	9.00	10.43	-1.43	10.14	7.93	2.21	9.29	8.50	0.79	8.29	8.57	-0.29
	S.D.	2.98	3.56		2.80	3.53		1.16	1.68		1.48	2.26	
2002 Term 3	Mean	10.43	7.93	2.50	8.71	7.07	1.64	10.00	7.43	2.57	8.86	7.79	1.07
	S.D.	2.66	3.92		2.37	2.49		2.78	1.45		2.80	2.11	
2002 Term 4	Mean	9.71	8.00	1.71	8.43	7.07	1.36	9.86	7.71	2.14	9.00	7.93	1.07
	S.D.	2.60	3.72		2.38	2.34		2.03	1.75		2.51	1.67	
2003 Term 1	Mean	7.71	5.21	2.50	9.86	6.57	3.29	9.43	6.93	2.50	8.29	8.29	0.00
	S.D.	2.25	2.40		3.09	2.95		2.13	3.06		1.39	2.12	
2003 Term 2	Mean	8.57	6.07	2.50	9.57	7.07	2.50	8.43	6.64	1.79	7.71	7.64	0.07
	S.D.	3.29	2.60		3.33	2.37		1.76	3.13		0.70	1.95	
2003 Term 3	Mean	6.43	3.71	2.71	7.14	4.57	2.57	8.86	5.50	3.36	7.71	7.43	0.29
	S.D.	1.29	2.55		1.64	2.58		1.46	2.72		0.70	1.29	
2003 Term 4	Mean	7.86	4.57	3.29	9.43	5.86	3.57	8.71	5.43	3.29	7.86	7.57	0.29
	S.D.	2.95	3.52		2.38	3.20		1.48	2.74		1.12	1.40	

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Table 11: Descriptive Statistics (Means and Standard Deviations) for Test and Control Groups in Year 12 over seven terms (N = 8)

Assess date		Ma_Know			Ma_Proc			Sc_Know			Sc_Proc		
		Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)	Test	Control	(Test-Control)
2002 Term 2	Mean	9.67	6.40	3.27	10.00	5.80	4.20	12.67	8.60	4.07	12.33	10.00	2.33
	S.D.	0.94	3.26		2.83	3.71		1.25	3.88		1.25	3.46	
2002 Term 3	Mean	9.00	7.80	1.20	9.00	8.20	0.80	12.33	7.40	4.93	12.00	9.40	2.60
	S.D.	0.82	2.14		1.41	1.72		1.25	3.26		1.41	2.73	
2002 Term 4	Mean	9.00	7.20	1.80	8.00	7.00	1.00	13.00	7.40	5.60	13.00	10.00	3.00
	S.D.	1.41	3.37		0.00	2.10		0.82	3.72		2.16	3.29	
2003 Term 1	Mean	8.33	7.00	1.33	10.33	7.40	2.93	12.00	7.20	4.80	12.00	9.20	2.80
	S.D.	0.94	1.41		0.94	2.58		1.63	4.53		1.41	2.86	
2003 Term 2	Mean	9.00	6.00	3.00	10.67	6.20	4.47	11.67	8.00	3.67	12.33	8.80	3.53
	S.D.	2.16	4.29		2.87	4.96		2.05	3.79		1.25	2.23	
2003 Term 3	Mean	9.67	7.00	2.67	11.00	7.20	3.80	11.00	6.80	4.20	11.67	8.00	3.67
	S.D.	1.70	3.85		2.45	4.45		2.45	3.66		1.70	2.10	
2003 Term 4	Mean	9.67	6.80	2.87	10.33	7.20	3.13	11.33	8.00	3.33	11.67	8.00	3.67
	S.D.	1.70	3.76		1.70	4.45		2.05	2.76		1.70	2.10	

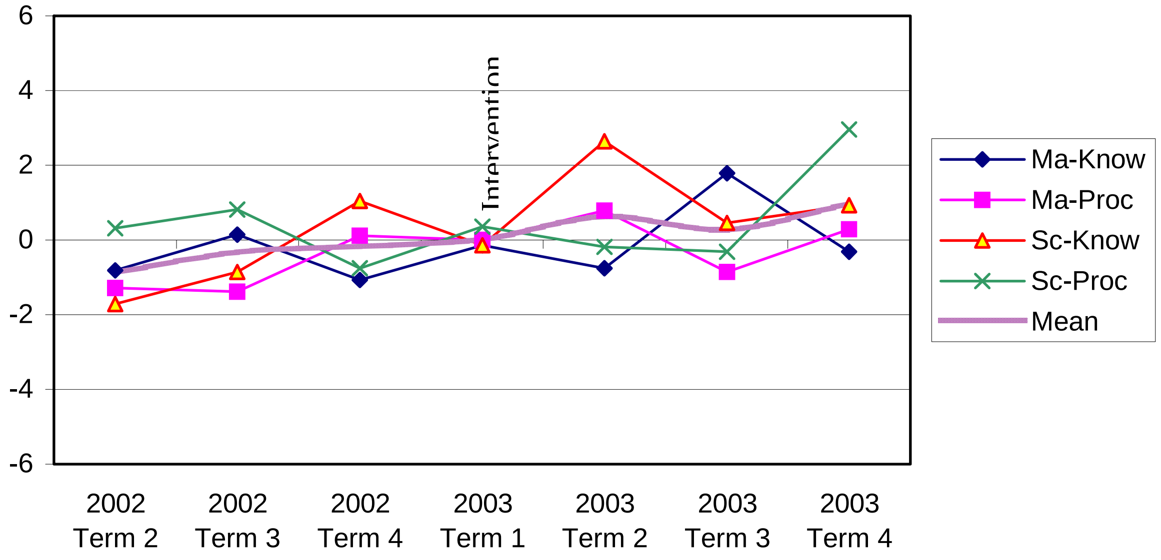

Figure 13 : Difference between Assessment Means (Test minus Control) for Year 8

A plot of the difference in assessment means, calculated by subtracting the control group (number of students = 7) mean from the test group (number of students = 4) mean, for each of the four assessment criteria, for the Year 8 group is shown in Figure 13. The mean of all four criteria is plotted on the same graph. This plot shows a very slight upward trend in assessment results by the test group over the control group following the intervention (which occurred in 2003 Term 1) which indicates that for the Year 8 group, the test group did increase their assessment results to a greater extent than did the control group, the effect being most noticeable in the scientific knowledge criterion of the test immediately following the intervention, and in the mathematical knowledge criterion in the second test following the intervention. The trend for each year level is analysed and tested for significance later in section 4.2.3.

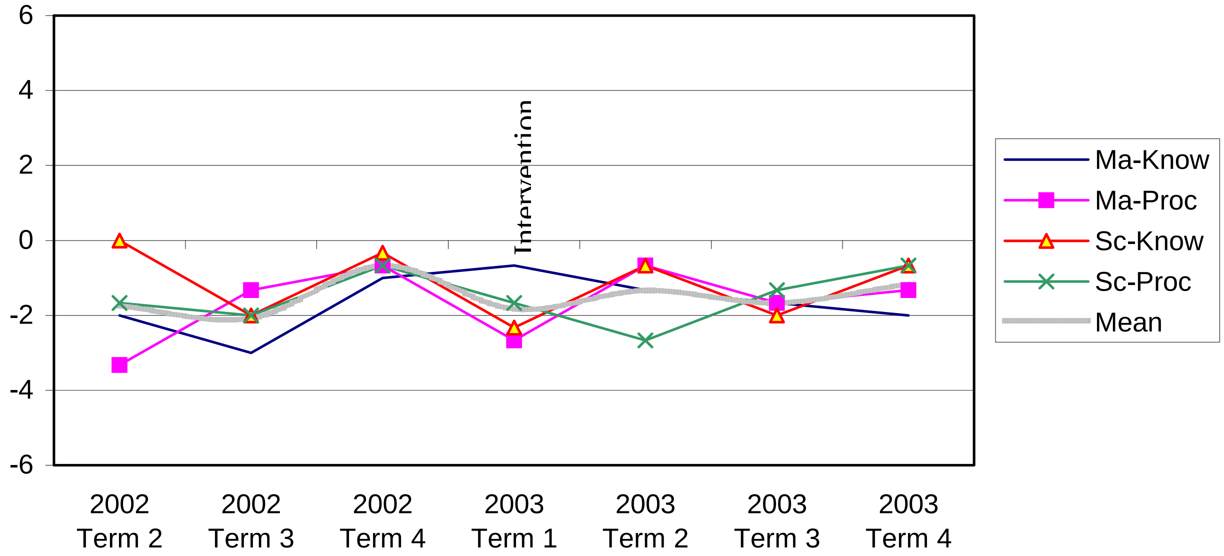

Figure 14: Difference between Assessment Means (Test minus Control) for Year 9

A plot of the difference in assessment means, calculated by subtracting the control group (number of students = 3) mean from the test group (number of students = 3) mean, for each of the four assessment criteria, for the Year 9 group is shown in Figure 14. The test group again shows an increase with respect to the control group in the scientific knowledge criterion in the assessment immediately following the intervention, but this general trend is reversed in the subsequent assessment.

A plot of the difference in assessment means, calculated by subtracting the control group (number of students = 10) mean from the test group (number of students = 3) mean, for each of the four assessment criteria, for the Year 10 group is shown in Figure 15. The test group show an increase in assessment results over the control group subsequent to the intervention, but for this group, the effect is most noticeable in the mathematical criteria. The difference in effect for the Year 9 and 10 groups may be attributed to the fact that this researcher was the Year 9 science teacher and the Year 10 mathematics teacher, but there was no test for significance performed to quantify this potential bias effect.

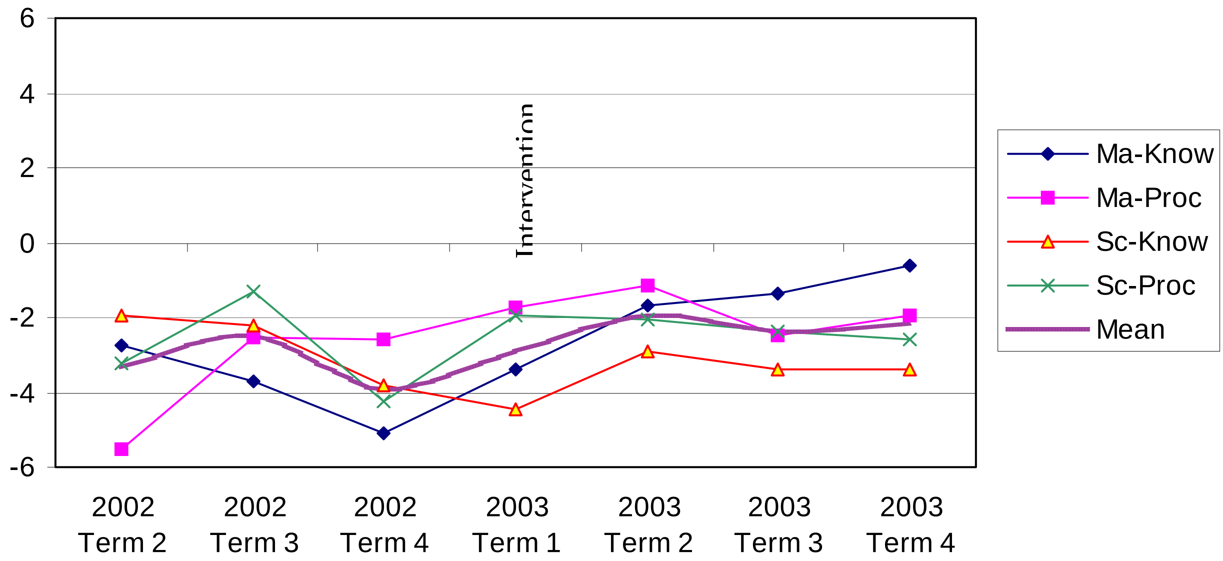

Figure 15: Difference between Assessment Means (Test minus Control) for Year 10

A plot of the difference in assessment means, calculated by subtracting the control group (number of students = 14) mean from the test group (number of students = 7) mean, for each of the four assessment criteria, for the Year 11 group is shown in Figure 16. A slight upward trend is noted, but the effect is less than for the previous Year levels.

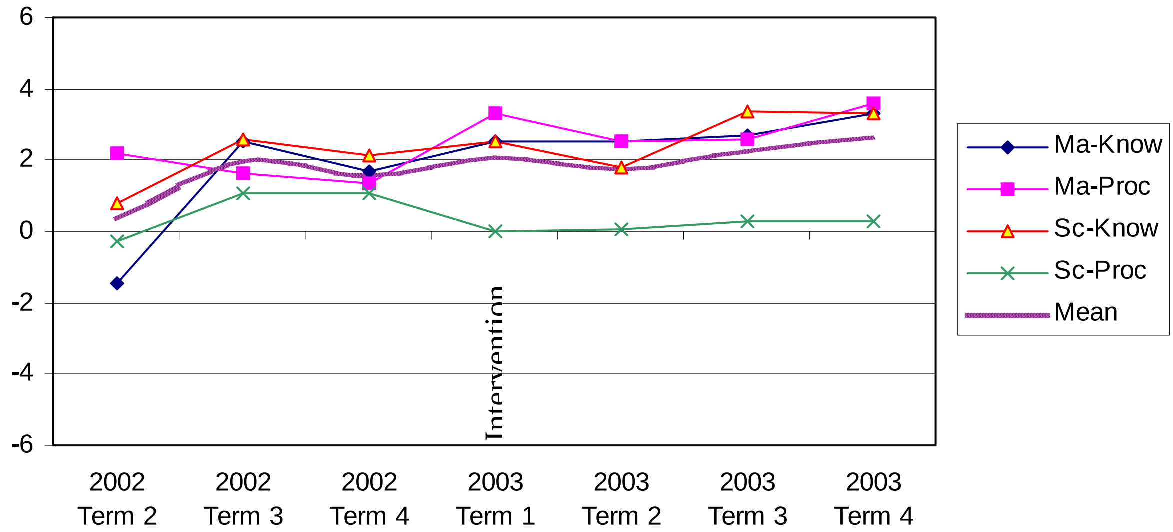

Figure 16: Difference between Assessment Means (Test minus Control) for Year 11

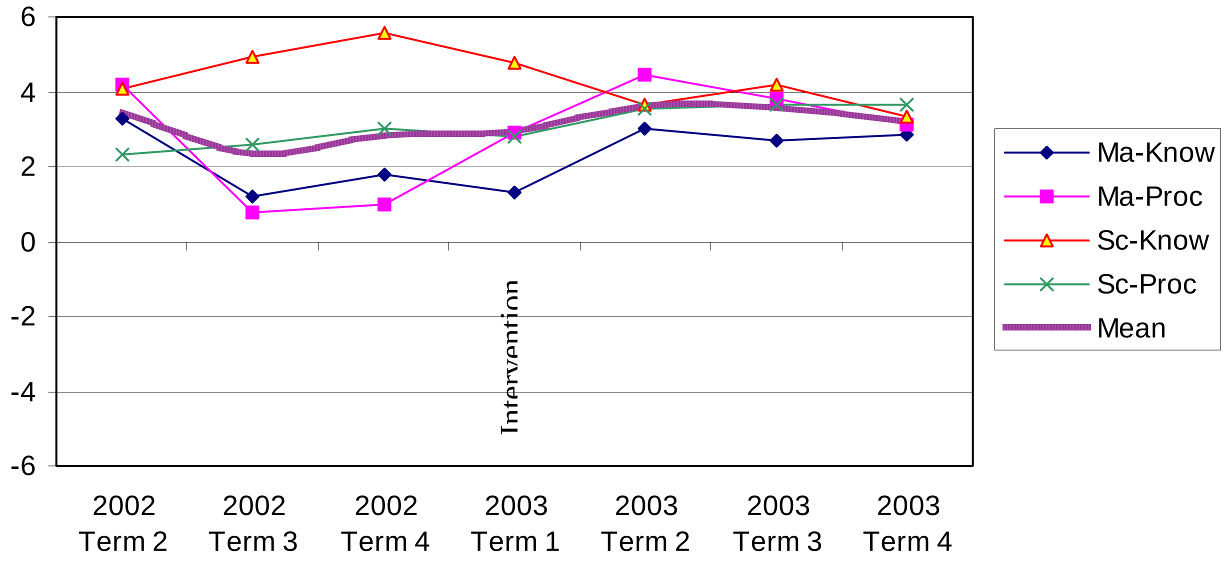

Figure 17: Difference between Assessment Means (Test minus Control) for Year 12

A plot of the difference in assessment means, calculated by subtracting the control group (number of students = 5) mean from the test group (number of students = 3) mean, for each of the four assessment criteria, for the Year 12 group is shown in Figure 17. It is noted that this plot shows that the test group's scientific knowledge assessment results lowered with respect to the control group's results after the intervention, whereas in the other three criteria the test group's assessment results increased with respect to the control group's results.

4.2.2 General Comparison of Before- and After- Grouped Means

In order to gain a clearer understanding of the general trends, and to compensate for differences in the topics covered in each term (as mentioned in the previous section), the assessment results for each of the three assessment instruments prior to and subsequent to the training session were averaged for the test and control groups, in each of the four assessment criteria. The academic results from term 1 2003 were not included as the assessments in that term were scheduled shortly after the training program (approximately two to four weeks), so it was believed that any effect at that stage would be transitional. The results of these calculations for each of the assessment criteria are presented in Tables 12 to 15, and are used to answer Research Question 1.

Table 12: Means and standard deviations of the three terms of assessments before and after intervention for the Maths-Knowledge Criterion

Year	Student Numbers test,control	Test Group					Control Group				
		Before		After		Diff in mean	Before		After		Diff in mean
		mean	sd	mean	sd		mean	sd	mean	sd	
8	4,7	16.13	1.73	15.50	1.84	**-0.63**	17.00	1.83	15.14	2.57	**-1.86**
9	3,3	16.17	1.28	16.50	0.47	**0.33**	19.17	0.98	19.00	1.39	**-0.17**
10	3,10	10.50	2.09	11.33	1.87	**0.83**	16.30	2.53	13.15	2.48	**-3.15**
11	7,14	14.57	2.75	11.43	2.66	**-3.14**	13.18	3.74	7.18	2.92	**-6.00**
12	3,5	13.83	1.09	14.17	1.87	**0.33**	10.70	2.98	9.90	3.97	**-0.80**

Table 13: Means and standard deviations of the three terms of assessments before and after intervention for the Maths-Process Criterion

Year	Student Numbers test,control	Test Group					Control Group				
		Before		After		Diff in mean	Before		After		Diff in mean
		mean	sd	mean	sd		mean	sd	mean	sd	
8	4,7	15.50	1.95	13.75	1.26	**-1.75**	16.79	2.68	13.64	3.07	**-3.14**
9	3,3	15.83	1.63	15.00	0.90	**-0.83**	18.50	1.74	16.83	1.47	**-1.67**
10	3,10	11.50	0.77	13.00	0.94	**1.50**	16.80	2.36	15.80	2.57	**-1.00**
11	7,14	13.64	2.53	13.07	2.55	**-0.57**	11.04	2.84	8.75	2.74	**-2.29**
12	3,5	13.50	1.83	16.00	2.39	**2.50**	10.50	2.65	10.30	4.62	**-0.20**

Table 14: Means and standard deviations of the three terms of assessments before and after intervention for the Science-Knowledge Criterion

Year	Student Numbers test,control	Test Group					Control Group				
		Before		After		Diff in mean	Before		After		Diff in mean
		mean	sd	mean	sd		mean	sd	mean	sd	
8	4,7	15.38	1.89	15.38	1.89	**0.00**	16.14	2.24	13.36	3.07	**-2.79**
9	3,3	17.33	1.98	16.17	1.36	**-1.17**	18.50	1.87	17.83	1.15	**-0.67**
10	3,10	12.50	1.41	12.67	1.25	**0.17**	16.50	2.25	17.50	1.68	**1.00**
11	7,14	14.57	2.10	13.00	1.57	**-1.57**	11.82	1.63	8.79	2.87	**-3.04**
12	3,5	19.00	1.12	17.00	2.19	**-2.00**	11.70	3.63	11.40	3.43	**-0.30**

Table 15: Means and standard deviations of the three terms of assessments before and after intervention for the Science-Process Criterion

Year	Student Numbers test,control	Test Group					Control Group				
		Before		After		Diff in mean	Before		After		Diff in mean
		mean	sd	mean	sd		mean	sd	mean	sd	
8	4,7	15.13	2.80	13.88	2.31	**-1.25**	14.93	2.96	12.64	2.75	**-2.29**
9	3,3	17.67	3.15	15.00	2.29	**-2.67**	19.83	1.49	17.33	2.26	**-2.50**
10	3,10	14.50	2.54	14.00	1.74	**-0.50**	18.90	2.01	17.50	1.81	**-1.40**
11	7,14	13.07	2.33	11.64	0.87	**-1.43**	12.14	2.03	11.32	1.57	**-0.82**
12	3,5	18.67	1.66	17.83	1.56	**-0.83**	14.70	3.17	12.40	2.14	**-2.30**

The differences in means of the test and control group, calculated by subtracting the control group result from the test group results, on the mean assessment results for the three assessments preceding the intervention and the three following the intervention have been plotted in Figure 18: Difference in means (test minus control) of before and after assessment results averaged over three assessment instruments. for each of the year levels and each of the assessment criteria. From this plot, and from the table, it can be seen that the test group generally improved their assessment results with respect to the control group, except for Years 9, 10 and 12 in scientific knowledge, and Years 9 and 11 in scientific processes. The statistical significance of this trend is tested in the next section.

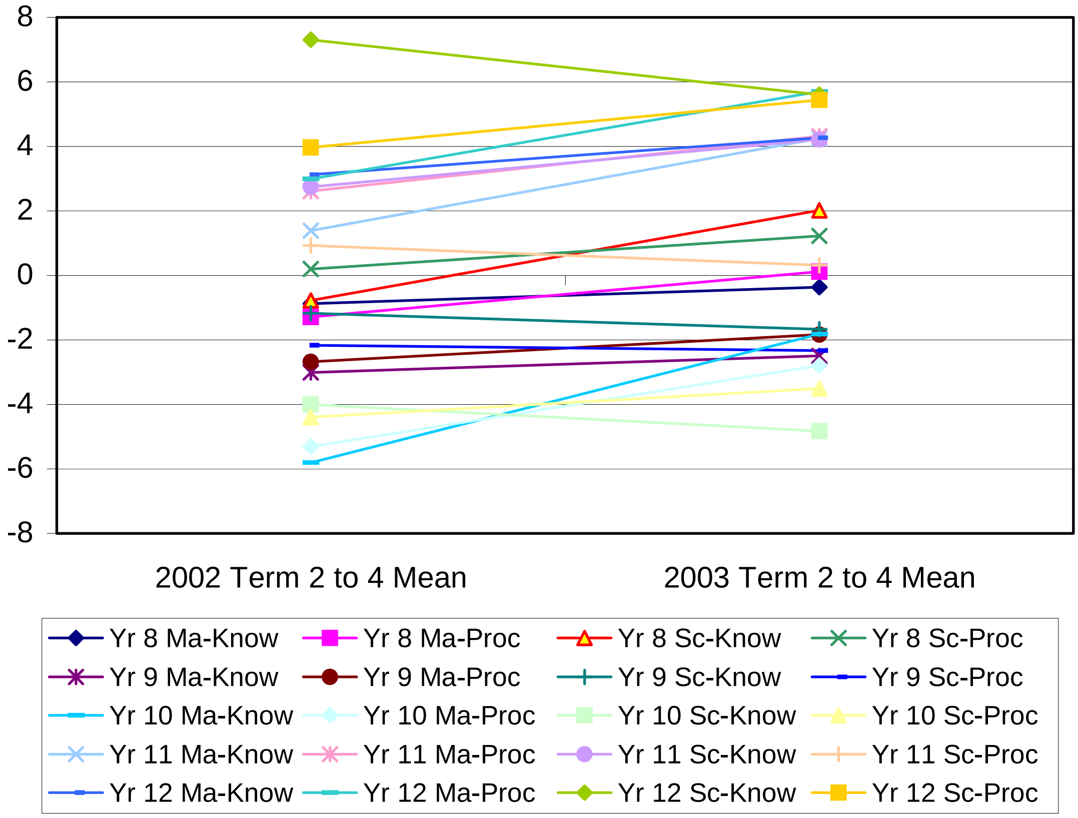

Figure 18: Difference in means (test minus control) of before and after assessment results averaged over three assessment instruments.

4.2.3 Student's t-score Analysis of Assessment Results

Student's t-score may be used to determine whether any significant change has occurred between the before- and after- assessment means for the test and control groups. For the purposes of this analysis, the t-scores comparing the test and control group means and standard deviations of their assessments before and after the training sessions were calculated. These are shown in *Table 16*, below.

In *Table 16*, N_f indicates the number of degrees of freedom of the data for that Year level ($N_f = N_{test} + N_{control} – 2$) and the 5% confidence value of t for that number of degrees of freedom is also given. For each of the Year levels, the test and control groups' means on the three assessment instruments have been compared using a t-score analysis testing whether the two groups were from the same population.

The "before" t-score analysis was performed to ascertain whether there were pre-existing differences between the two groups. It was expected that the test and control groups' assessments would not be significantly different before the intervention, which was not the case in Years 9 and 10. This may have been a result of the small sample size in Year 9 (N=3), and the personally observed fact that the Year 10 test group participants, being volunteers, were generally known by the teachers as the better academic students from that class. This introduced an inescapable bias into the results.

Had the intervention had the postulated effect of increasing student performance on assessment tasks, then the "after" t-score analysis would indicate a significant difference between the groups that did not exist before the intervention. The only assessment criteria in which this has been observed to occur is in the Year 11 Mathematics knowledge and process criteria, and the Year 12 Scientific process criterion.

In Year 10, the results on three of the criteria show that a pre-existing significant difference as indicated by the t-score became an insignificant difference following the intervention, showing that the intervention had the effect of making the two groups less disparate.

In the other Year levels and other assessment criteria, the intervention did not result in any change in the statistical significance of the t-score, indicating that there was no apparent effect.

Table 16: Student's t analysis of before and after assessment data for each year level and each assessment criterion, testing if the test and control groups were significantly different.

	Ma_Know	Ma_Proc	Sc_Know	Sc_Know
Year 8	**N_f = 9**	**5% = 2.26**		
Before	0.78	0.83	0.57	0.11
After	0.24	0.07	1.18	0.75
Year 9	**N_f = 4**	**5% = 2.78**		
Before	3.23*	1.93	0.74	1.08
After	2.95*	1.84	1.62	1.25
Year 10	**N_f = 11**	**5% = 2.20**		
Before	3.59*	3.73*	2.86*	3.15*
After	1.16	1.80	4.56*	2.95*
Year 11	**N_f = 19**	**5% = 2.09**		
Before	0.87	2.05	3.32*	0.94
After	3.23*	3.48*	3.59*	0.50
Year 12	**N_f = 6**	**5% = 2.45**		
Before	1.71	1.71	3.30*	1.97
After	1.71	1.94	2.49*	3.78*

* $p < 0.05$

4.2.4 Comparison of Assessment Totals Across Year Levels

In order to investigate the global effect of the intervention, and reduce any bias from the small sample size, the mean assessments for the three sets of results prior to and subsequent to the intervention were also calculated. For these purposes, all students were included regardless of year level. The results of this comparison are shown in Table 17. Neither t-score comparing the two groups (before an after intervention) indicates a significant difference, but it is interesting to note that the t-scores indicate that following the intervention, the group were more disparate – that is, the test group improved relative to the control group, even though the change was not mathematically significant.

Table 17: Comparison by t-test of the Mean Assessments Across Year Levels and Across Assessment Criteria

Group	Mean (before)	Standard Deviation (before)	Mean (After)	Standard Deviation (after)
Test (N=20)	9.85	3.45	9.28	3.22
Control (N=37)	9.74	3.75	8.38	3.80
t-Scores (N= 57) (5% = 1.67)	0.11		0.91	

4.2.5 Summary

With regard to the first research question, the analysis of the data show that the memory enhancement technique, as implemented by this researcher, did not provide any statistically significant change in students' results in the four assessment criteria used in the Queensland assessment.

Since the t-score analysis did indicate a positive though insignificant effect, there may be some slight justification for further future study using a larger sample size and more stringent research techniques, which is discussed later.

4.3 Research Question 2

Does the learning of a memory enhancement technique lead to a significant change in attitude towards science?

4.3.1 Analysis of TOSRA Scores

Should the intervention have had no effect, it would be assumed that the difference in means and standard deviations for the TOSRA scores on each of the scales (see Section 3.8.2 for an explanation of the scoring and scales) for the test group and the control group would not be significantly different, that is, a Student's t-score analysis would indicate that the two groups could have come from the same general population.

Table 18: Means, Standard deviations, and t-scores of TOSRA test scales for both groups, and the differences (Test Group – Control group (T-C)) between the means.

(N = 29, 5% = 2.05)

Scale	Group	Pre-Intervention TOSRA Score		Post-Intervention TOSRA Score		Difference
		Mean	SD	Mean	SD	(Post – Pre)
Social Implications of Science	Test	36.90	7.42	36.45	6.52	-0.45
	Control	31.00	9.79	30.44	9.38	-0.56
	Diff (T-C)	5.90		6.01		0.11
	t-score	2.37*		2.56*		0.19
Normality of Scientists	Test	36.95	7.11	37.10	6.50	0.15
	Control	37.56	7.82	37.00	6.65	-0.56
	Diff (T-C)	-0.61		0.10		0.71
	t-score	0.29		0.06		-0.24
Attitude to Scientific Inquiry	Test	37.60	7.36	38.85	6.66	1.25
	Control	28.11	9.06	29.33	7.69	1.22
	Diff (T-C)	9.49		9.52		0.03
	t-score	4.04*		4.70*		0.66
Adoption of Scientific Attitudes	Test	36.85	6.13	37.60	6.04	0.75
	Control	31.89	5.80	31.22	5.47	-0.67
	Diff (T-C)	4.96		6.38		1.42
	t-score	3.05*		4.09*		1.04
Enjoyment of Science Lessons	Test	36.60	7.44	35.85	7.23	-0.75
	Control	30.56	9.70	30.00	8.14	-0.56
	Diff (T-C)	6.04		5.85		-0.19
	t-score	2.44*		2.71*		0.27
Leisure Interest in Science	Test	37.50	7.47	37.10	7.59	-0.40
	Control	30.78	9.68	30.44	8.98	-0.33
	Diff (T-C)	6.72		6.66		-0.07
	t-score	2.71*		2.83*		0.12
Career interest in Science	Test	33.65	6.80	33.60	5.71	-0.05
	Control	28.44	9.83	28.22	9.33	-0.22
	Diff (T-C)	5.21		5.38		0.17
	t-score	2.12*		2.36*		0.24

* $p < 0.05$

The TOSRA scores for each of the scales were calculated for the test group and for those of the control group who completed the TOSRA test. The means and standard deviations of the scores for each of the TOSRA scales, before and after the intervention, as well as showing the differences between the before and after scores, and between the test and control groups are shown in Table 18.

The differences between the means and standard deviations for the pre-intervention scores and the post-intervention scores were analysed using the Student's t-score analysis as a test of significance, and the results shown Table 18 for each of the TOSRA test scales.

The differences in means of the control and test groups (test group – control group) for the per-intervention test score and the post-intervention test score are graphically plotted in Figure 19 for each of the TOSRA test scales for ease of comparison. This plot shows very little change in the means of scores pre-intervention to post-intervention, except in 'Adoption of Scientific Attitudes' and "Attitude to Scientific Inquiry" where a slight increase in the difference between the two groups is noted, and in 'Normality of Scientists' where a decrease is noted.

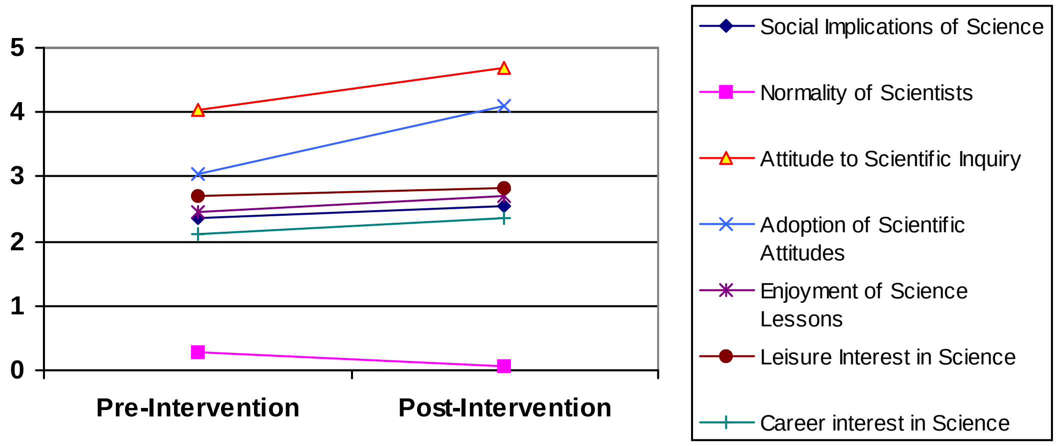

Figure 19: Plot of differences between test and control groups on TOSRA scores.

An analysis was performed using Student's t-score to determine whether there was any significant difference between the two groups' scores on the TOSRA scales, either before or after the intervention. Since the number of degrees of freedom was

29, a 5% significance level on the t-score comparison would be 2.05. Analysis of the t-score results indicates that although there were some significant differences between the scientific attitudes of the test group and the control group, particularly in "Attitude to Scientific Inquiry" (which has a confidence of almost 99% indicating the two groups were not from the same population) there was no significant change in attitude during the course of the study. The results of the t-score analysis are shown in Table 18.

4.3.2 Reliability of TOSRA Scales

The internal consistency of the TOSRA scales used in this facet of the research study was tested using the Cronbach coefficient alpha (Cronbach, 1951). Data from all of the students who completed the test were used in testing the reliability of the scales.

The individual students' scores on each of the TOSRA scales were divided into two – the first half and the second half of the ten questions associated with each scale. The means and standard deviations of the scores in the two halves were calculated, as were the mean and standard deviation of the total scores for each scale. These derived values were used to calculate the alpha coefficients for each scale, which are listed in Table 19.

Table 19 : Internal Consistency of the Scales in the Before- and After- Intervention TOSRA Tests

TOSRA Scale	Cronbach Alpha		Spearman-Brown-Prophecy-Corrected Cronbach Alpha	
	Before	After	Before	After
Social Implications of Science	0.97*	0.95*	0.99*	0.98*
Normality of Scientists	0.94*	0.93*	0.97*	0.96*
Attitude to Scientific Inquiry	0.97*	0.90*	0.99*	0.95*
Adoption of Scientific Attitudes	0.85*	0.89*	0.92*	0.94*
Enjoyment of Science Lessons	0.97*	0.91*	0.99*	0.95*
Leisure Interest in Science	0.97*	0.95*	0.99*	0.98*
Career interest in Science	0.96*	0.92*	0.98*	0.96*

* $p < 0.05$

Since the number of items in the scale influences the reliability of a scale, the value obtained by calculating coefficient alpha on the half sets of data as described above results in an underestimate the reliability of the scales. A correction for this effect was made using the Spearman-Brown Prophecy formula. The adjusted alpha coefficients are also listed in Table 19.

An alpha coefficient of 0.80 is generally considered to indicate that the set of scores is internally consistent. The calculations performed upon the data indicate that the TOSRA test as administered in this study was internally consistent with a high degree of reliability.

4.3.3 Summary

Although it is noted that there were significant differences between the two groups TOSRA scales scores existent prior to the intervention, there was no statistically significant change occurring as a result of the intervention.

4.4 Research Question 3

Does the learning of a memory enhancement technique lead to a significant improvement in the ability to recall lists of unrelated objects?

The test group had the list of 10 memory pegs and the 10 objects to memorise for a test nine months later. The control group were given the pegs and objects as a single list of 20 objects. The list of objects used is given in Table 6 on page 70. The list was presented to the control group during a single lesson, and they were asked to memorise the list for a test the following week. The test group learnt the memory pegs and the sample list of objects as part of the training process. No further instruction or assistance concerning the lists of objects was given to either group concerning the list. At the conclusion of the study (term 4, 2003), both groups were asked to recall the lists. After their first attempt, the test group was then given hints about the memory pegs, and allowed another opportunity to recall the objects. The control group was not given this opportunity, as it would not have meaning. The control group's score on the second test has therefore been set equal to their score on the first test. The means and standard deviations of the groups' results on the memory test are given in Table 20. The test group had noticeably higher scores on the memory test than the control group. A Student's t-analysis was completed, with the results being given in Table 20.

Comparisons between the test group and control group knowledge assessment prior to the intervention indicates that the two groups had similar recall ability.

The t-score analysis on Test #1 indicates a better than 99.9% probability that the training program had a significant effect on the ability of the students to memorise the list of objects. With the added advantage of the second test, the test group also performed significantly better than the control group.

Table 20: Means (and standard deviations) of memory test scores

	Test Group		Control Group		(Test minus Control)	t-score (N_f=27, 5%=2.05)
	Mean	SD	Mean	SD		
Test # 1	36.50	17.40	10.00	6.24	26.50	4.41*
Test # 2	49.75	18.74	10.00	6.24	39.75	6.16*

* $p < 0.05$

4.4.1 Summary

This result validates the assumption that the learning and practice of a memory enhancement technique for recalling lists of unrelated objects actually improved the test groups' ability to memorise lists of objects with respect to the control group, within the limitations of this research study.

4.5 Research Question 4

Does the amount of time spent practicing a memory enhancement technique improve performance on a test of recall?

Should there be a relationship between the memory recall and the time spent practicing, it would be expected that there would be a positive correlation between the two factors, that is, that the students who had spent more time practicing the technique would score better on the memory tests.

It should be noted that the students recorded and reported their own practice times, and may not have accurately represented the actual time spent – that is, the students may have over-stated (or understated) the amount of time they spent practicing the technique. The results of this part of the study should not be considered to be of the same rigour as those reported earlier.

The total practice times reported by the test group participants, against their score on the final memory tests are presented in Table 21, which has been sorted by the reported total time spent practicing.

Table 21: Total practice time versus memory test scores (sorted by total time)

Name	Total Time	Score 1	Score 2
TG-18	175	60	80
TG-5	100	40	50
TG-3	90	20	70
TG-7	80	50	50
TG-15	80	50	70
TG-6	80	10	20
TG-4	80	0	10
TG-1	60	50	60
TG-8	50	50	50
TG-12	50	40	45
TG-9	40	50	50
TG-11	40	30	50
TG-10	30	40	60
TG-14	30	30	40
TG-20	30	30	30
TG-17	30	20	40
TG-2	25	70	90
TG-13	10	40	50
TG-19	10	10	30
TG-16	5	40	50

These data have been plotted in Figure 20. The data trend has been plotted as a straight line of best fit, which indicates a general relationship between increased practice time and increased scores of the memory test, but given the apparent randomness of the data, it was decided that attempting any sort of linear regression analysis would be pointless.

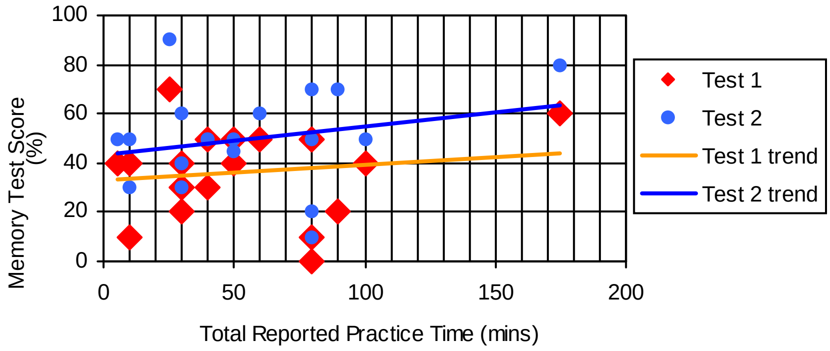

Figure 20: Total Practice Time versus Memory Test Scores (as a percentage)

It can be noted that the student who reported the greatest amount of practice time (TG-18) did indeed score one of the highest results but this is contrasted by the highest scoring student (TG-2) reporting one of the lowest times. It may be that this latter student grossly underestimated the time he spent practicing the technique, but there are no data to support nor disprove this conjecture.

4.5.1 Summary

There are sufficient indications in the data that suggest the value of this study being repeated. In such a study, tighter constraints on the validity of the self-reporting of time spent practicing would be needed such as a parental check for practicing at home. .

5 DISCUSSION AND CONCLUSIONS

5.1 Introduction

This chapter outlines the conclusions made as a result of this study and is divided into 3 sections.

- Section 5.2 answers the research questions individually, discussing them in the same order in which they were presented earlier in this thesis,
- Section 5.3 discusses in detail the various limitations on interpretation of the results gained by this study and the restrictions on the application of these findings.
- Section 5.4 outlines the recommendations for researchers and teachers from the understandings gained by this study.

5.2 Findings

5.2.1 Research Question 1: Effect on Assessment

There is some indication that the test group's academic assessment results improved following the training program. The graphs of the difference between the test and control group means on assessments (see Figures 13 to 18) show a general upward trend in the difference between the test group and control group's average assessment results; however, this is not consistent across all assessment criteria nor for all year levels.

Nevertheless, there is not sufficient confidence shown by the analysis using t-scores to warrant an outright assertion that the training led to any significant improvement.

Comparison of the student's average assessments, across all criteria, and irrespective of year levels showed a slight increase in the disparity between the two groups following the intervention, in that the test group's assessment results increased relative to the control group's results. Again, analysis of the significance using t-scores indicated that the difference was statistically insignificant.

In summary, there is some indication that there may have been an improvement of the test group's results over the control group's results, but this difference fails to meet the test for significance and the research question is therefore not validated by the data. That is, there is no statistically significant improvement in assessment results indicated by the training program for memory enhancement.

5.2.2 Research Question 2: Effect on Attitudes to Science

The analysis of student's attitudes to science, as assessed by the TOSRA test, showed some minor variation to attitudes (see **Error! Reference source not found.**) but again the analysis using t-scores indicates that these variations are statistically insignificant.

Of note is that the test group had a significant difference in some attitudes to science compared to the control group. This may have been due to the sampling method where two possible biases were evident.

Firstly, the test group consisted of volunteers, and tended to be students who were in my classes (as different to those students from the other teachers' classes), and since my classes, in my opinion, were generally the more "scientific" students (that is, those that scored better on science competitions, and subsequently undertook studies in senior science when they reached Year 11), this might be the cause of the bias. However, the test group and control group difference was maintained after the intervention, so no apparent significant change took place.

Secondly, the significant difference between the initial scores of the test group and the control group may be a result of the volunteer process. Since the test group were composed of volunteers, and the training program meant that "sport" had to be foregone for two weeks, the test group was composed of students who probably had a more sincere desire to improve their academic abilities instead of those with an overriding interest in sport. It is this researcher's opinion that the test group students may have started with an overall more favourable impression of science and scientists because they also have a higher opinion of the value of education.

Despite the differences noted in the test and control groups, the analyses of these data indicate that the training program appeared to have no effect on the participant's attitudes to science.

5.2.2.1 Research Question 3: Effect on Ability to Recall Lists of Objects

The analysis of the memory test results of the 9-month period in which they were expected to remember the objects indicates that the test group performed significantly better (with a confidence of greater than 99%) than the control group even though the control group had to recall the list for only one week.

It is unlikely that the test group benefited from "practicing" or "rehearsing" the list of objects, as it had no meaning for them outside the focus of this study, by which I mean that it is unlikely, given the reported practice times, that the students spent much time revising the list of objects.

Furthermore this researcher remembers quite clearly the very first list learned upon being taught this technique, even though that training took place 23 years ago. This anecdotal datum does not in itself validate the assertion that the first list is more memorable in any way, but does result in this researcher not being surprised by the results obtained by the test group.

The result of this research appears to validate the training program as a method for improving the ability to recall lists of objects, within the limitations imposed by the small sample size and limited scope of the study, as discussed later.

5.2.3 Research Question 4: Effect of Time Spent Practicing the Technique

The data show a general trend supporting the hypothesis that increased practice time results in an increased ability to remember lists of objects, but the data are so disparate (refer to Figure 20) that the trend must be considered unproved. The analysis of time spent practicing the technique therefore appears to indicate that the time spent practicing the technique has no clear bearing on a test group students' subsequent recall, despite an intuitive hypothesis that this should be the case.

A significant problem associated with making any conclusion from the data was the suspect reporting by students of the time claimed to be spent studying the recall technique (see discussion above). It appears that none of the test group put in any significant practice time, nor for any extended number of weeks. Indeed, only one student reported spending more than two hours practicing the technique over the period of nine months, and most spent less than one hour.

It is likely that another researcher working with a larger and more motivated group of participants may be able to establish a clear relationship supporting this hypothesis, but the above data does not do so. That is, there appears to be no relation between time spent practicing and the score on he recall test.

5.2.4 Summary of Findings

In summary, the results of this study indicate that the students who learned the technique had a significantly improved ability to remember a list of objects, but the other research questions remain unproved.

5.3 Limitations

5.3.1 Transference to other areas

Since Edwards' (1988) reported that using the deBono CoRT-1 program within a science framework yielded significant academic achievement in the humanities area but not so much in the sciences, it was considered important that results in other subjects were examined also. Similar spreads and trends of results in other subjects were noted, but the criteria of assessment varied so much that a simple direct comparison was rendered problematic. Given the lack of conclusive evidence in the science and mathematics results, analysis of the humanities results was abandoned after noting that there was no obvious nor significant variation from the observed science and mathematics results; that is, there was no apparent improvement in the humanities results either.

5.3.2 Sample Size

This research was conducted in a very small school, on what was necessarily a small sample of students. All of those students not taking part in the test group, and on whom a complete set of assessment data was available, composed the control group. In order to reduce the possible effect of the study of different units within science and mathematics, analyses were performed using data on year level groups. These groups were perforce very small, and therefore the statistical test required a very dramatic difference to be significant. It may be that a similar research performed on a much larger group would result in a more positive outcome than this trial on a limited sample.

5.3.3 Volunteer Bias

Since the test group was composed of volunteers who were sacrificing their weekly sports sessions for two weeks, it is believed that the test group were composed of students who were more interested in academic performance than sport. This introduced an unavoidable bias into the analysis of academic performance, in that the test group were generally the more capable science and mathematics students attending the target school. Had the t-score analysis indicated a barely significant difference between the two groups following the intervention, doubt would have been raised on the validity of the analysis given the difference between the two groups prior to the intervention. Since the results obtained do not clearly validate the hypothesis, the concern raised by this bias proved unnecessary. Should another researcher duplicate or extend this area of research, it should be considered better for that researcher to obtain a larger population sample size and use a matched-pairs analysis to remove this bias.

5.3.4 Memory Technique Practice Time

It may be that the students who scored poorly on the memory test were those that did not practice the technique at all, but erroneously or falsely reported the amount of time spent as higher than they had actually done. It is also possible that some of the students who scored highly on the test underestimated the amount of time they spent practicing the technique. There is no evidence that either of these situations occurred but both would explain the observed randomness and lack of the expected general upward trend. It would be problematical to redesign the data gathering technique to more accurately get an indication of the time spent practicing, as is the case in the gathering of any data self-reported by students. A possible solution may be to have supervised practice sessions, which would ensure accurate reporting of the minimum time spent practicing, but still leave an uncertainty about the maximum time.

5.3.5 Other Factors

The researcher acknowledges that there are many factors to consider when dealing with the educational process, any of which can bias or distort the valid allocation of causality as being the result of the intervention. It is acknowledged that a design with a larger number of students and classes would have allowed for the investigation of whether or not the memory technique was limited in its content or context application, and how influences such as teacher or teaching effect, student motivation, the increase in maturity of the students could have affected the learning outcomes. Unfortunately, a much larger sample to have experimental and comparison was not possible for this limited introductory study.

5.4 Recommendations

5.4.1 For Research

The indications of improved academic performance, although not being significant, are, in this researcher's opinion, sufficient to warrant further study, with the following procedural notes:

- A larger group would be preferable.
- More follow-up monitoring may be useful – it is noted that none of the test group participants reported maintaining practice of the technique for more than five weeks, which in all likelihood invalidated the analysis of the relationship between practice time and memory test score.

5.4.2 For Teaching

The theory underlying the 'memory peg' method may have implications for the way in which education occurs. Firstly, there is evidence that it clearly leads to better recall of lists of objects. While this is not applicable to every aspect of school learning, there are many elements of school subjects that lend themselves to simply being memorised. Learning the sequence of elements in the periodic table or the names of the bones of the human body both constitute lists that may be better recalled using this technique.

There is also some slight evidence from this study that transference to academic assessment may occur. Sufficient, perhaps, to be worthy of consideration that all students should be taught the technique and the methods of using it.

Since the memory peg method is centred around techniques of sensory-rich visualisation, and has been proven by this research to be effective in assisting recall of lists of unrelated objects, there is a recommendation to teachers that they provide similar sensory-rich visualisations as part of the teaching process in order to facilitate student recall of fundamental facts and principles.

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7 APPENDIX A : TRANSCRIPT OF TEACHING TECHNIQUE WITH MEMORY PEGS

<Portions of the following enclosed in brackets and in italics are not part of the transcript, but explanatory notes. Also, please be aware that this was presented to a group of high school students, so the language used is not as stringent as that normally used in a thesis, but it is appropriate to the audience.>

Learning to memorise a list of unrelated objects is probably the hardest thing to do. It is much easier to learn facts, like what you do in class, where things are sensible and related – if you remember one bit of a thing it is easier to remember the whole of it. Like in physics or science or maths, if you can remember the formula, you usually can remember what all the symbols mean. or what the formula does than just trying to remember a list of letters and numbers.

The technique that I'm going to teach you has been around a long time and I learned it in 1983. It's what I used when demonstrating my memory for you that time.

<This refers to a demonstration I did in which I learned a list of 20 objects and recounted them forwards, backwards and in random order, to a group of students as an introduction, most of whom then signed up for the lessons.>

It is based on an idea of memory pegs. A memory peg is somewhere that you can hang a bit of information. The peg itself contains a numbering system so that you automatically remember things in a given order. You can use it to remember lists, phone numbers, the sequence of steps you took in pulling something apart, or whatever.

The first part is to learn the pegs – now don't look at me like that, it's not hard to do. The way I will teach you the pegs you can use to memorise anything, even boring stuff like schoolwork. The pegs have a specific use, but also will show you how to go about memorising things, and that's what I want to talk to you about first, then we'll get back to the pegs.

Firstly, think of a teacher you had in primary school. <*pause*> OK, you're probably remembering one of two types of teacher – the one that you had a lot of fun with, that you really liked, or one that you really hated, right ? <*student generally agree*>

That's because of the way your memory works – it's a survival thing built in. Experiences that are very painful or very pleasurable are important. Think about learning about hot things. The first time you touch a fire, your hand gets brunt – it hurts. It's important to remember that to avoid getting hurt again – so the memory is strong – it's easy to learn – it's a powerful memory – so next time you think about touching a fire you'll remember that it hurts. It's not like an exam – you get a couple of questions wrong, so what – it doesn't hurt that much until your folks get your report, right ? No, with the fire it's a survival thing – it's really important – next time you might die.

So, here's the first memory trick that works – if you're really scared of what's going to happen if you fail the test, you'll be better able to learn. Yeah, it works OK, as long as you don't stress out too much. Stress gets in the way of learning – if you're too stressed out, you won't learn stuff very well. But the idea of being a bit scared helping you learn is why teachers have been threatening students for thousands of Years – and you thought that it was just because we hated kids, right ?

OK, so what's your favourite subject? <*pause while students respond.*> Do you do better in your favourite subject? Lots of people do – you like it, it's fun, so you do more of it, and you learn – and you get better at it. Just about everyone does better at subjects they enjoy. That's the other side – you remember pleasurable things as well as hurtful or nasty things. If you have fun learning, you'll remember stuff better. Of course, that's not always easy with some of the stuff you have to learn, right?

So, how does your brain actually remember things. Well, I don't know, and I haven't seen anything that says anyone else knows either. But it seems reasonable that you remember some sort of reality. This is a bit tricky to explain, but you don't have to understand it, just use it. What does it mean to experience an object. If you've had a baby brother or sister and seen them grab something for the first time – they look at it, grab it, and then what do they do? <*students answer*> Yep, put it in their mouths, which does two things – they taste it – which can be revolting depending on what they've picked up – and at the same time they've smelt it.

So – sight, touch (which is temperature and softness/hardness and texture), taste and smell – and there is hearing too if its got a bell in it, which lots of baby toys do. Everything you come across has the five senses helping you to remember it – all your senses send information to your brain, and they are all stored. What colour if your front door? <*pause while students answer*> That's easy. Is it hard or soft? Is it smooth or rough? <*pause while students answer*> You know that too. What's it taste like? <*pause while students answer – some do*> How many of you actually have tasted your front door? So where did that knowledge come from – somewhere in your brain there is a memory of what painted wood tastes like – somewhere, sometime, you tasted painted wood and the memory is still there! It might have been 12 or 15 Years ago, but you still remember – what a memory!

Close your eyes. Go on. Now think about sucking on a really sour lemon. <*some students respond*> That memory is so strong, you actually can taste that lemon still – that's how powerful your memory can work – it can actually cause your taste buds to shrivel up, just because, Years ago, you sucked on a lemon. So, what's your excuse for not getting 100% in your exams?

OK, so it's not that easy. Part of the problem is that when you are learning school work, and being lazy, you aren't really involved in it – maybe, maybe, you're looking at what the teacher is doing, maybe you're looking out the window, maybe you're listening to your friend talk about the movie last night, and your other senses are caught up feeling hungry, uncomfortable on the chair, a bit warm in the heat, with the crow outside, and the murmur from next door, and your sore foot from PE this morning, and what is it with that itch on the back of your neck, and while all this is going on the teacher is talking about how important a meat pie is in working out the circle of an area – or at least that's what you think it was about!

My point is this – the more real you make it –by being involved, using all your senses-, the easier it is to remember. Add emotion – either fear or pleasure, and the more easier it is to remember. They're the two secrets of memory – simple aren't they?

Let's learn the memory pegs. That's going to be the proof that I know what I'm doing. I'm going to teach them to you using these ideas and you'll see that you'll be able to remember them for ages – actually forever if you want, just the same way I remember them 20 Years after learning them – the same way that you remember that fire is hot. That's not something that you get 5/10 for!

The pegs all have a picture with them because we get more information from vision than other senses, but it's important to use all the senses.

<These were roughly drawn on the blackboard, but copies of the original drawing were not made. The verbal descriptions given should be adequate for the reader to get the idea. Each line on the table had the number, the word, and a rough drawing of the peg. >

The first peg is tea. The picture is a cup of tea with the number one drawn on the side. You can add taste, heat, smell, perhaps the sound of a kettle boiling.

The second peg is Noah – Noah is the guy in the bible who took animals onto the ark in twos, so you can see where the two fits in. Given lots of animals, sounds and smells come easy. Taste, well, whatever!

The third peg if May. The sounds and words have been chosen for a reason I'll tell you about later. The picture for May is three tall trees, or three maypoles if you know what a maypole is. The trees can be eucalypt, so you can smell them. May is autumn, so there's a lot of things you can do with smells and breezes.

The fourth peg is Ray. Four rays of light beaming through a window – one of those old-fashioned windows you sometimes see in old houses with the cross of wood, making four panes of glass, so four rays of light.

Five is Law. The sheriff's badge has five points and he is a lawman.

Six is jaw. You can use a jaw with six teeth, say the jaw of jaws, the shark from the movie, or a boxer's jaw with only 6 teeth left.

Seven is Key. I use a fancy gold key in the shape of a seven.

Eight is Fee. A price tag of one hundred million dollars ($100,000,000) – has eight zeros.

Nine is Pea. A pea pod with nine peas in it.

Ten is toes. Ten toes, yeah.

Tea, Noah, May, Ray, Law, Jaw, Key, Fee, Pea, Toes.

So let’s go through these, and you suggest some sights, smells, sounds, and touch sensations that go with each one.

<The student responses have not be reported separately as most were incorporated in what follows. >

It’s important to be relaxed and receptive, and focussed during this next bit, which is the actual learning of the pegs. Firstly stand and stretch a little.

Sit and close your eyes gently. You don’t have to keep them closed, but it helps cut distractions. If you hear outside noises, just let them wash over you.

Take three slow deep breaths in … and out … in … out … in … out.

Now picture the first peg. Tea. A cup of tea. It has a one on the side of it. Pretend that you are taking a sip of the tea. What does it taste like. What does it smell like. Feel the cup. Is it hot, or warm, or is it ice tea? What sort of cup is it – put in details – is it porcelain, fine china, is it decorated. Detail is important. Put in as much detail as you can, remembering to use all of your senses. The first peg is Tea.

The second peg is Noah. Imagine Noah leading the animals onto the ark, two by two. You can imagine the smells; hear the sounds of the animals calling out. What sort of day is it – is it cold and rainy or clear and bright.

The third peg is May – imagine three tall trees in May. You can hear the sound of the wind in the leaves, and see the leaves moving.

The fourth peg is Ray. Imagine four means of light, like what would come through a window with crossed bars and four panes. Is the light warm or cool ? Bright or Dim ?

The fifth peg is Law. Imagine the five-pointed sheriff’s star of the lawman. You might be able to smell the leather of his clothes too.

The sixth peg is Jaw. Imagine a jaw with 6 teeth, or Jaws the shark with 6 teeth.
Seven is Key. Imagine a key in the shape of a 7. What is it made of? Is it cool to the touch?

Eight is Fee. Imagine a fancy looking price tag for $100000000 – it has 8 zeros on it.

The peg for nine is Pea. Imagine 9 fresh ripe peas in a pod.

The peg for ten is toes. Imagine your ten toes wiggling. Do they smell ?

<At this point, we revised the list a couple of times, and ran through it a few times until everyone was very sure of the pegs. The exact wording is irrelevant, as it was basically repetition of the list of pegs in various ways, up and down, and random.>

Now the pegs are somewhere to hang a memory. They have no special magic about them other than as an aid to your fantastic memory – to help you get it sorted out into order. The simplest use for them is to memorise a list of objects, which we're now going to do. I'm going to get you to memorise a list of objects – totally unrelated objects – because that is the hardest thing to do. See, if you wanted to remember how you took a bit of machinery apart, it's easier because some things are obvious – like the casing or front panel goes on after the bits that go inside. But memorising a list of unrelated things is harder – does this one go before or after that one ? Well, you'll just have to remember, because there won't be any clues.

Now, to use the pegs, all you have to do is to mentally associate the peg with the thing you're trying to remember. You need to use all 6 senses – yeah, six. You've got the five physical senses: sight, touch, taste, hearing, smell; but you've also got a sense of humour, right ? Remember what I said at the start – things that are frightening or fun are remembered better. You could use scary images, but let's have fun instead.

<The list was written on the board next to the list of pegs.>

The first thing on our shopping list is hippopotamus. Now we need to associate hippopotamus with our cup of tea. How can we do that? Well, we could picture a hippopotamus sitting in a chair sipping on a cup of tea, with their little finger stuck out, acting all posh, or maybe we could picture the hippopotamus having a bath in a cup of tea, with a shower cap on, scrubbing their back with a scrubbing brush. Yeah, you think that's funny – OK, use that – put as much detail in it as you can – maybe the hippopotamus is sitting on the teabag. Close your eyes- that's just to cut out the distractions – and imagine the hippopotamus soaking in a cup of Earl Grey – or whatever, put in all the detail you can.

OK, Item two is a motorbike. How can you associate that with Noah?

<Student suggestions have not been transcribed – since the suggestions were guided towards certain pictures, these are described below, but students were at liberty to choose any visualisation they liked. After each object, time was allowed for students to think / visualise their association The description below is a summary of about 15-20 minutes of discussion.>

So Noah is this really old guy in a robe, hooning around on a motorbike rounding up animals, or maybe leading two motorbikes onto the ark – whichever you think is funniest.

Item three is rattrap. rattrap and tree, you could use a rattrap trapping trees, or trees growing rattraps like fruit.

Item four is worm. You could imagine a worm sitting in a deckchair sunning itself in the four rays of light.

Item five is banana. The sheriff walks down the street, sees a bad guy, and shoots him dead with a banana.

Item six is a double-decker bus. Imagine Jaws biting on a double-decker bus.

Item seven is a yellow submarine, like in the Beatle's song. The key could open the door of the submarine, or maybe wind it up – it has to surface after firing a missile so that the captain can wind it up.

Item eight is a snake. Imagine what sort of snake would cost $100000000.

Item nine is television set – maybe you open a pod and there are nine little television sets in there showing pictures of split pea soup advertisements.

Item ten is peanut paste. Peanut paste and toes – yeah, I don't have to say more do I?

<The list was revised briefly, - the visualisations as described above, and then the list was erased from the board. The group then responded to questions about which item was numbered x, and what was item x in the list. A couple of students were hesitant about a couple of items when asked, and were assisted with clues where necessary. By the end of 15 minutes, all students could recite all ten items in forward or reverse order, and in random order in response to questions.
This terminated the training session.>

8 APPENDIX B : THE MEMORY PEGS

Table 22 lists the first twenty memory pegs. The pegs represent a phonetic symbol that is also a word associated with a visualisation element. Thus, the peg for number the one, ‘tea’, represents the consonant ‘t’ as well as a ‘cup of tea’ which is the visualisation element for that peg. For use of the pegs as a visualisation element, see “APPENDIX A : Transcript of Teaching Technique”.

The pegs for multiple-digit numbers are composed of the pegs for each of the digits. For example the peg for 34 is a combination of the pegs for 3 and 4 (may / m and ray / r) to give a word containing an ‘m’ and a ‘t’– which could be moor, mars, meer(cat), mir (the space station), or any other similar word.

The exact word used for the pegs greater than 10 is not important. What is important is that the person creating the peg uses a sensory rich visualisation to firmly establish the peg in their mind / brain. For ease of recall, it is important that the visual cue is closely associated with the number - for example, for peg 19, a tap could be in the shape of a 19 or a top could be a football jersey number 19

Table 22: The memory pegs

Number	Peg Name	Letter/s	Suggested Visual Cue
0	zzz	z, s	*< not used except to build multi-digit pegs >*
1	tea	t, d	cup of tea with letter 1 on side
2	Noah	n	Noah with 2 animals
3	may	m	3 tall trees in may
4	ray	r	rays of light through 4 pane window
5	law	l	5 pointed lawman's badge
6	jaw	j, sh, ch, g	jaw with 6 teeth
7	key	k, ck, c	key in shape of a 7
8	fee	f, v, ph	price tag for $8
9	pea, bay	p,b	9 peas in a pod / bay in shape of 9
10	toes	t + z	10 toes
11	tot, tat	t + t	
12	tin, ton	t + n	
13	tom, tam	t + m	
14	tear, tar	t + r	
15	tool, tail	t + l	
16	tissue, taj	t + j	
17	tick, tack	t + k	.
18	toffee, toff	t + f	
19	top, tap	t + p	
20	nose	n + z	
21	net, nut	n + t	
22	nan, nun	n + n	
123	dynamite	d + n + m	

9 APPENDIX C : THE TOSRA TEST

The TOSRA test was developed by Fraser (1981) and consists of seventy statements (listed in Table 23, below.), ten each of seven subcategories (scales). The scales are given in *Table 4*. The scoring system is explained in Table 5.

In a very large population containing a normal distribution of opinion, the theoretical mean for each category would be 30, corresponding to 10 answers of “not sure”. Fraser (1981) applied the test to many students (N=1337) and found a range of means in the seven scales from approximately 25 to 40. In this research, the test is not used as an absolute, but rather as a measure of observable change as a result of the training program. Thus the results of interest reflect gains or losses in scores rather than the absolute scores. The 70 statements are given in Table 23.

Table 23: The TOSRA Statements

Num	Scale	+/-	Statement
1	Social Implications of Science	+	Money spent on science is well worth spending.
2	Normality of Scientists	-	Scientists usually like to go to their laboratories when they have a day off.
3	Attitude to Scientific Inquiry	+	I would prefer to find out why something happens by doing an experiment than by being told.
4	Adoption of Scientific Attitudes	+	I enjoy reading about things which disagree with my previous ideas.
5	Enjoyment of Science Lessons	+	Science lessons are fun.
6	Leisure Interest in Science	+	I would like to belong to a science club.
7	Career interest in Science	-	I would dislike being a scientist after I leave school.
8	Social Implications of Science	-	Science is man's worst enemy.
9	Normality of Scientists	+	Scientists are about as fit and healthy as other people.

Num	Scale	+/-	Statement
10	Attitude to Scientific Inquiry	-	Doing experiments is not as good as finding out information from teachers.
11	Adoption of Scientific Attitudes	-	I dislike repeating experiments to check that I get the same results.
12	Enjoyment of Science Lessons	-	I dislike science lessons.
13	Leisure Interest in Science	-	I get bored when watching science programs on TV at home.
14	Career interest in Science	+	When I leave school, I would like to work with people who make discoveries in science.
15	Social Implications of Science	+	Public money spent on science in the last few Years has been used wisely.
16	Normality of Scientists	-	Scientists do not have enough time to spend with their families.
17	Attitude to Scientific Inquiry	+	I would prefer to do experiments than to read about them.
18	Adoption of Scientific Attitudes	+	I am curious about the world in which we live.
19	Enjoyment of Science Lessons	+	School should have more science lessons each week.
20	Leisure Interest in Science	+	I would like to be given a science book or a piece of scientific equipment as a present.
21	Career interest in Science	-	I would dislike a job in a science laboratory after I leave school.
22	Social Implications of Science	-	Science discoveries are doing more harm than good.
23	Normality of Scientists	+	Scientists like sport as much as other people.
24	Attitude to Scientific Inquiry	-	I would rather agree with other people than do an experiment to find out for myself.
25	Adoption of Scientific Attitudes	-	Finding out about new things is unimportant.
26	Enjoyment of Science Lessons	-	Science lessons bore me.
27	Leisure Interest in Science	-	I dislike reading books about science during my holidays.
28	Career interest in Science	+	Working in a science laboratory would be an uninteresting way to earn a living.
29	Social Implications of Science	+	The government should spend more money on scientific research.
30	Normality of Scientists	-	Scientists are less friendly than other people.
31	Attitude to Scientific Inquiry	+	I would prefer to do my own experiments than to find out information from a teacher.
32	Adoption of Scientific Attitudes	+	I like to listen to people whose opinions are different from mine.
33	Enjoyment of Science Lessons	+	Science is one of the most interesting school subjects.

Num	Scale	+/-	Statement
34	Leisure Interest in Science	+	I would like to do science experiments at home.
35	Career interest in Science	-	A career in science would be dull and boring.
36	Social Implications of Science	-	Too many laboratories are being built at the expense of the rest of education.
37	Normality of Scientists	+	Scientists can have a normal family life.
38	Attitude to Scientific Inquiry	-	I would rather find out about things by asking an expert than by doing an experiment.
39	Adoption of Scientific Attitudes	-	I find it boring to hear about new ideas.
40	Enjoyment of Science Lessons	-	Science lessons are a waste of time.
41	Leisure Interest in Science	-	Talking to friends about science after school would be boring.
42	Career interest in Science	+	I would like to teach science when I leave school.
43	Social Implications of Science	+	Science helps to make life better.
44	Normality of Scientists	-	Scientists do not care about their working conditions.
45	Attitude to Scientific Inquiry	+	I would rather solve a problem by doing an experiment than be told the answer.
46	Adoption of Scientific Attitudes	+	In science experiments, I like to use new methods which I have not used before.
47	Enjoyment of Science Lessons	+	I really enjoy doing science lessons.
48	Leisure Interest in Science	+	I would enjoy having a job in a science laboratory during my school holidays.
49	Career interest in Science	-	A job as a scientist would be boring.
50	Social Implications of Science	-	This country is spending too much money on science.
51	Normality of Scientists	+	Scientists are just as interested in art and music as other people are.
52	Attitude to Scientific Inquiry	-	It is better to ask the teacher the answer than to find it out by doing experiments.
53	Adoption of Scientific Attitudes	-	I am unwilling to change my ideas when evidence shows that the ideas are poor.
54	Enjoyment of Science Lessons	-	The material covered in science lessons is uninteresting.
55	Leisure Interest in Science	-	Listening to talk about science on the radio would be boring.
56	Career interest in Science	+	A job as a scientist would be interesting.
57	Social Implications of Science	+	Science can help to make the world a better place in the future.

Num	Scale	+/-	Statement
58	Normality of Scientists	-	Few scientists are happily married.
59	Attitude to Scientific Inquiry	+	I would prefer to do an experiment on a topic than to read about it in science magazines.
60	Adoption of Scientific Attitudes	+	In science experiments, I report unexpected results as well as the expected ones.
61	Enjoyment of Science Lessons	+	I look forward to science lessons.
62	Leisure Interest in Science	+	I would enjoy visiting a science museum at the weekend.
63	Career interest in Science	-	I would dislike becoming a scientist because it needs too much education.
64	Social Implications of Science	-	Money used on scientific projects is wasted.
65	Normality of Scientists	+	If you met a scientist, he would probably look like anyone else you might meet.
66	Attitude to Scientific Inquiry	-	It is better to be told science facts than to find them out by experiments.
67	Adoption of Scientific Attitudes	-	I dislike listening to other people's opinions.
68	Enjoyment of Science Lessons	-	I would enjoy school more if there were no science classes.
69	Leisure Interest in Science	-	I dislike reading newspaper articles about science.
70	Career interest in Science	+	I would like to be a scientist when I leave school.

10 APPENDIX D : SAMPLE EXAMINATION PAPERS

The following two sample examination papers (one from year 10 mathematics and nine from year 9 science) were written by the author during the period of study, and are included as examples only.

The students used in the intervention were from several year levels, and the exact examinations used varied with year level, some being written by the author, and some being written by other teachers.

All examination shared a similar division into criteria, and the students' results were reported on the term reports using these criteria. The data gathered as part of this research was recorded from the school-filed copies of the students' reports.

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Year 10 Mathematics – Term 4 2002

Trigonometry, Consumer & Business Maths, Solutions of Equations & Inequations

End of Unit Test

Student Name	**Class**	**Date**

Exam Conditions Read these before starting test !	♦ Supervised test in class time – no assistance given ! ♦ Time Allowed: 45 minutes. No perusal time. ♦ A scientific calculator is necessary ♦ **A ruler is necessary for part A. A protractor would help in part B.** ♦ No notes, translators, dictionaries or other books are permitted for Part A. **Books and notes may be used for part B** ♦ Write answers neatly in dark ink, in the spaces provided ♦ Unless otherwise shown, each question is worth 1 mark. Questions with (a) and (b) sections are therefore ½ mark each for (a) and (b).

This section to be completed by the teacher marking this exam.			
Recall (Knowledge of basic facts, definitions, etc)	Marks Out of 10	> 8 (80 %) = A > 6.5 (65 %) = B > 4.5 (45 %) = C > 2.5 (25 %) = D < 2.5 (25 %) = E	Result
Cognitive (Simple Application)	Marks Out of 10	> 4.5 (45 %) = next > 2.5 (25 %) = D < 2.5 (25 %) = E	Result
Problem Solving (More difficult applications)	Marks Out of 10	> 6 (60 %) = A > 4 (40 %) = B < 4 (40 %) = C	

Do not open exam paper until told to do so.

PART A : No Books or Notes Permitted

Recall (Knowledge of basic facts, definitions, etc)

Q.1. What is the formula for working out the ***sine*** of an angle in a triangle ?

(a) opposite side divided by adjacent side
(b) opposite side divided by hypotenuse
(c) adjacent side divided by hypotenuse
(d) adjacent side divided by opposite side
(e) hypotenuse divided by adjacent side

Answer (*Circle one of*) A B C D E

Q.2. What is the value of ***cos(90^o)*** ?

Answer . . . .

Q.3. ***Trigonometry*** means

(a) to measure angles and work out their sine, cosine, and tangent
(b) the same as geometry
(c) to create maps, and measure heights of trees
(d) trigon = triangle, metron = measure, so "measuring triangles"
(e) "something difficult you have to study in maths"

Answer (*Circle one of*) A B C D E

Q.4. John says "the trigonometric ratios of an angle stay the same no matter how big the triangle gets", but Jack says "As the triangle gets bigger, the ratios change". Which one is correct ?

(a) John's statement is always true
(b) John's statement is only true for triangles on flat surfaces
(c) Neither John or Jack has made a true statement
(d) Jack's statement is true for triangles on flat surfaces
(e) Jack's ststeament is always true

Answer (*Circle one of*) A B C D E

Q.5. A person standing on a cliff at the ocean, sees a boat some distance away and at an angle of 15^o down. This 15^o angle is most correctly called:

(a) the bearing
(b) the angle of depression
(c) the elevation
(d) the slope
(e) the hypotenuse

Answer (*Circle one of*) A B C D E

Q.6. The line connecting the points on the Earth's surface which are the same distance from the equator are called:

(a) parallels of latitude
(b) meridians of longitude
(c) great circles
(d) the poles
(e) lines of bearing

Answer (*Circle one of*) A B C D E

Q.7. Which of the following equations is <u>**incorrect**</u>?

(a) final value = original value - depreciation
(b) savings = income - expenditure
(c) amount paid back = principal + interest
(d) profit = cost price – selling price
(e) discounted (sale) price = ticket price - discount

Answer (*Circle one of*) A B C D E

Q.8. The **inverse operation** of **multiplication** is:

(a) addition
(b) subtraction
(c) division
(d) reciprocal
(e) square root

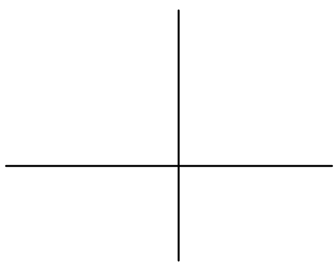
Answer (*Circle one of*) A B C D E

Q.9. Which of the following is a <u>***quadratic equation***</u> ?

(a) $y = 3x^2 + 4$
(b) $y = mx + c$
(c) $x + 3 = 4$
(d) $y = {}^3/_x + 2$
(e) $y^2 + x^2 = 16$

Answer (*Circle one of*) A B C D E

Q.10. When x and y are both in a quadratic equation, and the values of y are plotted for all values of x, roughly draw the shape of the graph that you would get (assuming all coefficients are positive), and give the one-word description (name) of it.



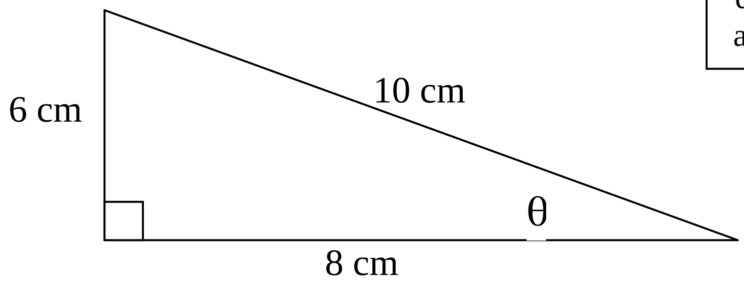
Answer . . . .

Simple Application

(Show all of your working to qualify for full marks.)

IMPORTANT NOTE
Unless you are told otherwise in the question, the diagrams are **not** drawn to scale.

Q.11. Calculate the **tan** of the angle θ in this triangle :



Answer . . . tan θ = ...

Q.12. What is the value of the angle θ (in degrees) in the previous question ?

Answer . . . θ = ...

Q.13. A student works part-time at the local shopping centre, and earns \$30 a week. Every Friday night she goes to the Blue-light disco, which costs \$3, and buys one soft drink (\$2). Every week she spends \$8 on cosmetics and lunchtime snacks. If she has no other expenses, how long will it take her to save up enough money to buy an \$85 pair of jeans?

Answer . . . .

Q.14. A half-pack-a-day smoker spends $5 a day on cigarettes. How much will they have spent buying cigarettes between starting smoking at 18, and dying of lung cancer at 48 ? (Remember to add the 7 extra days for the "leap years" every fourth year!)

Answer . . . .

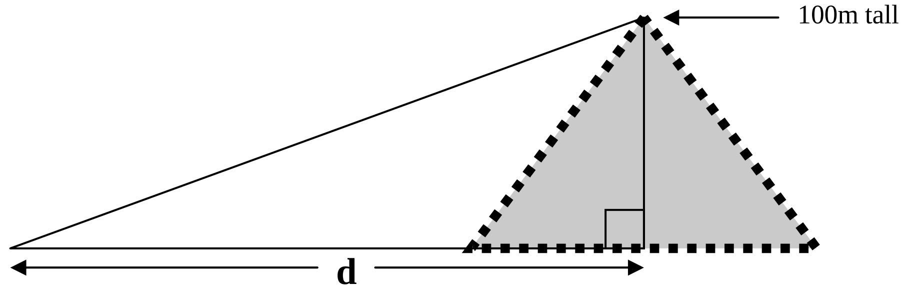
Q.15. A camera is available for $480 cash, or on no-deposit terms of $50 a week for 3 months. How much interest will be paid if you buy it on these terms?

Answer . . . .

Q.16. Where do the graphs of $\mathbf{y = x^2 + 2x + 1}$ and $\mathbf{y = x + 1}$ cross ? You must solve this question algebraically, not by drawing the graphs !

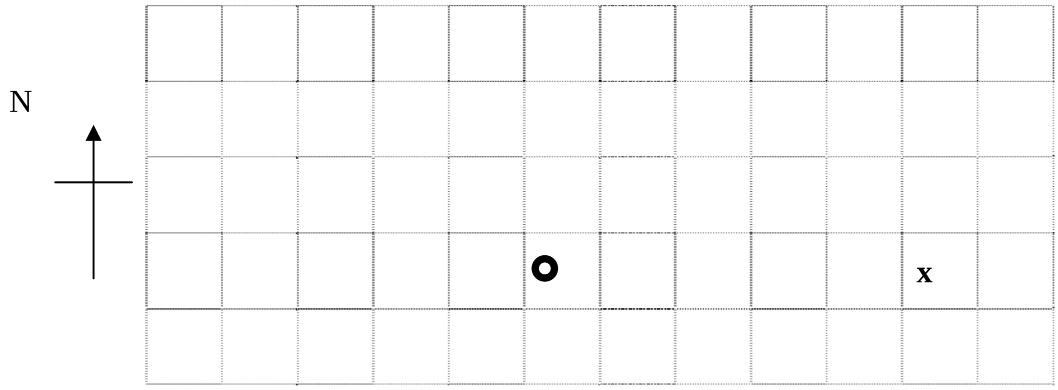
Answer . . *At the point/s* . . . .

Q.17. Workers want to create a pyramid. They intend to build a ramp to drag the blocks of stone up. The available trucks cannot drag the blocks of stone up a slope of angle greater than **17^o** above the horizontal. The last block of stone will be 100 metres above the ground. How long will the base of the ramp (d) have to be ?



Answer . . . .

Q.18-20. The following map is drawn accurately to scale of 1cm = 10 m.. The grid lines are 1 cm apart.



Q.18. Accurately draw a point, and mark it 'A', that is 30m north-east of the circle.

Q.19. According to the map and scale, how far apart are the circle and the x ?

Answer . . . .

Q.20. What bearing (in degrees) is the x from the circle ?

Answer . . . .

Note : the rest of this test will be done next lesson, and it is **open book** – you may bring your textbook and notes and refer to them during the test.

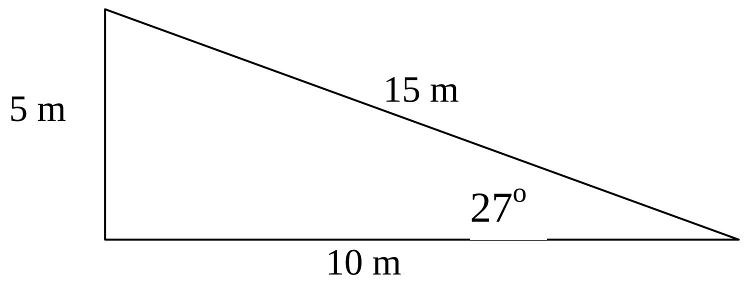
Student name . . . .

PART B : Books and Notes Permitted

Problem Solving (More difficult applications)

(Show all of your working to qualify for full marks.)

Q.21. Is the following triangle a right-angled triangle ? You must explain how you arrived at your answer! (It is not drawn to scale !)



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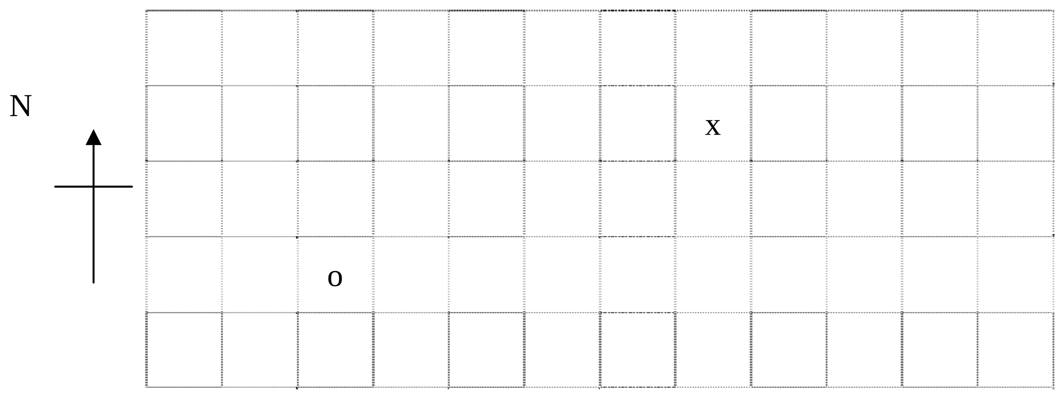
Q.22. At a certain time of day, when the sun is exactly 42^o above the horizon, the shadow of a tree stretches for 15m from the base of the tree. How high is the tree ?

Answer . . . .

Q.23. Locate and draw a point which is on a bearing of **N 45 E** from the 'o' and **N 270 E** from the 'x'.



Q.24. You have three things only: an A4 sheet of paper (22 cm by 29 cm), 30 cm ruler and a pencil. Describe how you could accurately draw an angle of 45^o.

....

....

....

....

....

Q.25. The metre was originally defined as $^1/_{40,000,000}{}^{th}$ (one 40-millionth) of the circumference of the Earth. We use a system of 360^o in a circle, because the ancient civilisation that 'discovered' the circle had a number counting system based upon 6 and 60 (6x60=360). For every degree of latitude that you travel north of the equator, how far have you travelled in kilometres?

Answer . . . .

Q.26, 27. (*The table on page 456 might be useful*).You have two choices in taking out a loan to buy a second-hand car for $5000. You could either take out a simple interest loan at 16% p.a. over 4 years, or a reducing interest loan at 14% over 6 years. Which one works out cheapest overall, and by how much? (**2 marks**)

Answer . . . .

Q.28. For your first full-time job in sales management in a one-person shop, you are offered a choice of salary packages. You can earn a flat rate of $15 / hour for a 40-hour week, or get $150 a week retainer plus 10% commission on sales. The accounts for the last three years show an average annual turnover of $230,000. The commission sounds attractive because if you work harder, you will get paid more, but then again, if you do not work hard enough, you will get paid less. Assuming that you will be able to maintain the same average sales turnover, which salary package will give you the most ?

Answer . . . .

Q.29. Find the solution/s of $\mathbf{5x + 2 = 3x^2}$

Answer . . . .

Q.30. Find the simultaneous solutions of $\mathbf{x + y = 3}$ and $\mathbf{y = -x2 + x + 6}$

Answer . . . .

---### END OF TEST ###---

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Year 9 Science - Biology Unit
End of Term 4 Test 2002

Student Name	Class	Date

Exam Conditions Read these before starting test !	• Supervised test in class time – no assistance given ! • **Time Allowed : 45 minutes.** No perusal time. • Non-programmable calculators are permitted but not necessary • No notes, translators, dictionaries or other books are permitted • Write answers neatly in dark ink, in the spaces provided • Unless otherwise shown, each question is worth 1 mark. Questions with (a) and (b) sections are therefore ½ mark each for (a) and (b).

This section to be completed by the teacher marking this exam.			
Knowledge of Content (Recall of facts)	Marks Out of 15	> 12 80 %) = A > 9.75 (65 %) = B > 6.75 (45 %) = C > 3.75 (25 %) = D < 3.75 (25 %) = E	Result
Problem Solving – Simple	Marks Out of 10	Simple < 25% = E < 50 % = D Simple > 50 % and Complex < 25 % = C < 60 % = B > 60 % = A	Result
Problem Solving – Complex	Marks Out of 5		
Scientific Processes	Assessed on the basis of correct use of terminology, correct spelling, correct use of numbers, and communication skills in presenting clear and precise definitions and discussions. Rated A (very good) to E (very poor)		Result

Do not open exam paper until told to do so.

Knowledge of Content – recall of facts and definitions

Q1. Describe what is meant by the term "an *adaptation*".

....

....

....

Q2. There are several types of adaptations. A certain type of fish lays millions of eggs at once in the bed of a stream. Is this a type of

(a) structural adaptation
(b) reproductive adaptation
(c) behavioural adaptation
(d) genetic adaptation
(e) something that is not an adaptation

Answer (*Circle one of*) A B C D E

Q3. As part of a food chain, there is the sequence A ➔ B. This means :

(a) A is eaten by B
(b) A grows up to become B
(c) B is eaten by A
(d) nutrient flows from B to A
(e) B grows up to become A

Answer (*Circle one of*) A B C D E

Q.4. Most energy that is passed along a food chain originally came from where ?

....

Q.5. Organisms that break down dead organisms into their component chemicals are called :

(a) producers
(b) consumers
(c) herbivores
(d) carnivores
(e) decomposers

Answer (*Circle one of*) A B C D E

Q.6-15. Fill in the missing information in the following table, concerning measuring the characteristics of a freshwater environment.

(1 mark each)

Property	**Measuring Device**	**Description of how device is used**	**Effect on Living Things**	**Unit of measurement**
temperature	6.	immerse device in water for several minutes	7.	degrees
toxins	chemical analysis	varies, depending on toxin	poisonous, can be fatal or make organism sick	parts per million or molar
dissolved gases	gas meter	depends on gas being measured. Usually a sample of the water is	8.	9.
pH	10.	turn on device, place it in water until display stops changing and read value	living things have narrow range of acceptable values	no units
water depth	ruler	11.	deeper water is darker and less plant growth. Shallow water is warmer. Shallow water exposes fish to bird predators.	12.
rate of flow	ruler and stopwatch	drop a floating object into the water and time how long it takes to be swept along a certain distance.	13.	metres per second
turbidity	14.	lower the device into water until it just disappears. measure depth at which it disappears.	higher turbidity exposes organisms to predators	15.

Problem Solving – Simple
(You need to get 50 % of these right to get a 'C' or better in problem solving)

Q.16. Name a single type of Australian animal or plant (for example a kangaroo, a koala, and an eucalypt tree) and describe one adaptation (of any type) that it has that enables it to withstand the environmental conditions in Australia.

the animal..

the adaptation ....

how the adaptation helps...

....

....

Q.17. A particular type of bird has feet with very long thin toes that spread out at wide angles, with webbing between them. This is an adaptation that helps the bird survive in its habitat. In what type of habitat would very long thin webbed toes be an advantage, and why?

habitat...

reason ....

....

Q.18. When setting up an aquarium, a student tests the water before placing the fish in, and finds that the pH is 2.0. Is this a safe reading for an aquarium ? Why / why not ?

....

....

....

Q.19. When testing the rate of flow of a stream, a student finds that the water moves 20 metres in 4 seconds. What is the rate of flow of this stream ?

Answer . . . .

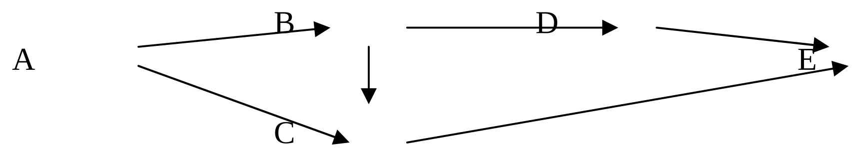
Q.20. A limpet is a shell that attaches itself very tightly to a rock. A scorpion fish is a marine fish (that is, an ocean fish) that has very large 'fluffy' fins and tail. Which one is more likely to be found living near a rocky headland, and which would be found in deep water ?

rocky headland ....

deep water ....

Q.21-22. Some possums are known to eat grasshoppers, and all grasshoppers eat grass. Draw a food chain with these three organisms.
(**2 marks**)

Q.23-25. The following diagram shows a simple food web, with organisms A, B, C, D, E being various types of plants and animals.



Q.23. Which animal or plant is a producer ?

Answer (*Circle one of*) A B C D E

Q.24. Which animal or plant is a first order consumer ?

Answer (*Circle one of*) A B C D E

Q.25. Which animal or plant is most probably a carnivore and not an insectivore ?

Answer (*Circle one of*) A B C D E

Problem Solving – Complex
(You need to get some of these right to get a ‘B’ or an ‘A’ in problem solving)

Q.26-27. In South America there lives a very strange type of plant. It has a large sticky flower that closes on insects, traps and dissolves them. A scientist wants to classify the plant as a producer or consumer. What does the scientist need to do in order to correctly classify this plant ? (Your answer must contain an experiment or question to be answered, and a result that would indicate one or the other - that is, your answer must say something like "the scientist should test for ……. and if the result is …… then the plant would be a ……..")

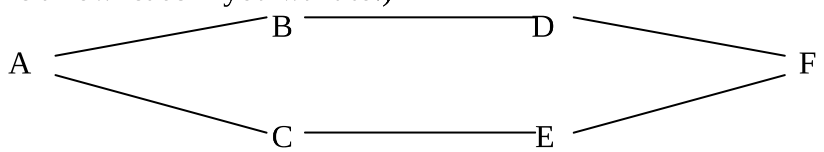
(**2 marks**)

....

....

....

Q.28-30. (**3 marks**) This diagram represents a food web, with organisms A, B, C, D, E being various types of plants and animals. (The arrowheads have been left off so that you can get no help for questions 3, 23, 24, and 25, but B & C eat A, and D eats B, E eats C and F eats D & E. Also, A is a producer. You can draw the arrowheads if you want to.)



During a drought, most of animal C die out because they need a lot of water. The other animals and plants are not affected by the lack of water.

Q.28. What effect will this situation have on the number of animal E ?

(a) the number of E will increase because they will eat animal D & B
(b) the number of E will increase because there is more A to eat
(c) the number of E will decrease because of lack of food
(d) the number of E will decrease because D will eat them
(e) all of the animals will die out because of the drought

Answer (*Circle one of*) A B C D E

Q.29. What effect will this situation have on the number of animal D, and why ?

....

....

Q.30. What effect will this situation have on the number of animal B, and why ?

....

....

11 APPENDIX E : CALCULATION OF MEANS

The following tables (Table 24 to Table 33) give the individual results to show how the means were calculated.

Table 7 to Table 11, in section 4.2.4, summarise the means and standard deviations of the test and control groups for each Year level, and gives the difference between the means.

These data are used to investigate research question 1 – whether the intervention technique had any effect on the students' performance on their normal school assessment in science and mathematics.

11.1 Test Group

Table 24: School assessment results for the test group, Year 8

Year = 8	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Ma_Know							
TG-11	14	13	11	13	14	12	11
TG-12	11	10	11	11	9	10	10
TG-19	9	9	8	8	8	8	8
TG-9	9	12	12	12	10	12	12
Mean	10.75	11.00	10.50	11.00	10.25	10.50	10.25
Ma_Proc							
TG-11	14	14	12	11	11	9	10
TG-12	10	10	10	10	11	8	7
TG-19	9	9	9	9	9	9	9
TG-9	7	10	10	10	7	10	10
Mean	10.00	10.75	10.25	10.00	9.50	9.00	9.00
Sc_Know							
TG-11	11	12	14	13	12	12	13
TG-12	10	8	12	10	11	9	9
TG-19	9	8	9	8	7	8	8
TG-9	6	12	12	13	12	10	12
Mean	9.00	10.00	11.75	11.00	10.50	9.75	10.50
Sc_Proc							
TG-11	14	14	14	11	13	10	14
TG-12	8	8	8	8	7	10	7
TG-19	7	7	7	7	7	7	7
TG-9	10	12	12	12	10	10	9
Mean	9.75	10.25	10.25	9.50	9.25	9.25	9.25

Table 25: School assessment results for the test group, Year 9

Year = 9	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Ma_Know							
TG-13	11	12	12	12	12	11	11
TG-18	11	9	9	10	11	11	11
TG-6	11	9	13	11	12	10	10
Mean	11.00	10.00	11.33	11.00	11.67	10.67	10.67
Ma_Proc							
TG-13	11	11	10	9	10	10	11
TG-18	9	9	9	9	9	9	9
TG-6	9	14	13	8	12	10	10
Mean	9.67	11.33	10.67	8.67	10.33	9.67	10.00
Sc_Know							
TG-13	13	13	14	13	13	11	13
TG-18	11	8	8	10	11	10	11
TG-6	13	12	12	12	9	10	9
Mean	12.33	11.00	11.33	11.67	11.00	10.33	11.00
Sc_Proc							
TG-13	14	14	14	14	14	13	12
TG-18	8	7	7	7	7	8	8
TG-6	14	14	14	12	9	10	9
Mean	12.00	11.67	11.67	11.00	10.00	10.33	9.67

Table 26: School assessment results for the test group, Year 10

Year = 10	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Ma_Know							
TG-16	10	9	9	9	9	10	10
TG-5	4	7	3	6	8	6	7
TG-7	8	7	6	6	8	3	7
Mean	7.33	7.67	6.00	7.00	8.33	6.33	8.00
Ma_Proc							
TG-16	7	10	9	9	9	7	7
TG-5	6	8	8	8	11	8	8
TG-7	5	8	8	9	11	7	10
Mean	6.00	8.67	8.33	8.67	10.33	7.33	8.33
Sc_Know							
TG-16	7	6	7	6	7	7	7
TG-5	8	8	10	10	9	8	8
TG-7	11	9	9	6	10	10	10
Mean	8.67	7.67	8.67	7.33	8.67	8.33	8.33
Sc_Proc							
TG-16	7	6	6	7	7	7	7
TG-5	11	14	11	12	12	11	10
TG-7	11	12	9	9	10	10	10
Mean	9.67	10.67	8.67	9.33	9.67	9.33	9.00

Table 27: School assessment results for the test group, Year 11

Year = 11	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Ma_Know							
TG-1	11	14	14	11	13	7	11
TG-14	7	6	7	7	8	7	7
TG-17	11	10	6	6	6	7	7
TG-2	5	14	12	6	6	5	5
TG-20	9	9	9	8	8	8	8
TG-3	6	9	9	5	5	4	4
TG-4	14	11	11	11	14	7	13
Mean	9.00	10.43	9.71	7.71	8.57	6.43	7.86
Ma_Proc							
TG-1	14	12	12	14	14	8	11
TG-14	6	4	4	4	6	6	6
TG-17	11	11	11	11	11	9	10
TG-2	9	9	8	10	8	5	8
TG-20	9	9	8	9	9	9	9
TG-3	8	8	8	8	5	5	8
TG-4	14	8	8	13	14	8	14
Mean	10.14	8.71	8.43	9.86	9.57	7.14	9.43
Sc_Know							
TG-1	11	14	13	11	11	10	10
TG-14	9	9	9	9	7	7	8
TG-17	8	8	9	9	8	9	7
TG-2	8	8	8	9	8	7	8
TG-20	11	13	11	11	8	10	10
TG-3	9	6	7	5	6	8	7
TG-4	9	12	12	12	11	11	11
Mean	9.29	10.00	9.86	9.43	8.43	8.86	8.71
Sc_Proc							
TG-1	8	14	14	8	8	8	8
TG-14	7	7	6	7	7	7	7
TG-17	7	7	7	7	7	7	7
TG-2	7	5	8	7	8	7	7
TG-20	10	10	9	9	7	9	10
TG-3	8	8	8	9	9	8	7
TG-4	11	11	11	11	8	8	9
Mean	8.29	8.86	9.00	8.29	7.71	7.71	7.86

Table 28: School assessment results for the test group, Year 12

Year = 12	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Ma_Know							
TG-10	9	8	11	7	12	12	12
TG-15	9	9	8	9	7	8	9
TG-8	11	10	8	9	8	9	8
Mean	9.67	9.00	9.00	8.33	9.00	9.67	9.67
Ma_Proc							
TG-10	8	11	8	11	14	14	12
TG-15	8	8	8	9	7	8	8
TG-8	14	8	8	11	11	11	11
Mean	10.00	9.00	8.00	10.33	10.67	11.00	10.33
Sc_Know							
TG-10	14	14	14	14	14	14	14
TG-15	11	11	12	10	9	8	9
TG-8	13	12	13	12	12	11	11
Mean	12.67	12.33	13.00	12.00	11.67	11.00	11.33
Sc_Proc							
TG-10	14	14	15	13	14	14	14
TG-15	11	11	10	10	11	11	11
TG-8	12	11	14	13	12	10	10
Mean	12.33	12.00	13.00	12.00	12.33	11.67	11.67

11.2 Control Group

Table 29: School assessment results for the control group, Year 8

Year = 8	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Ma_Know							
CG-30	11	10	12	14	11	11	11
CG-31	10	11	10	8	9	5	8
CG-34	12	8	10	7	7	4	8
CG-35	10	10	9	10	10	7	9
CG-36	15	13	15	13	14	13	13
CG-38	13	13	14	13	14	11	13
CG-39	10	11	11	13	12	10	12
Mean	11.57	10.86	11.57	11.14	11.00	8.71	10.57
Ma_Proc							
CG-30	11	14	10	10	7	10	11
CG-31	10	9	5	8	8	7	3
CG-34	5	12	7	8	7	8	4
CG-35	11	11	11	11	7	7	9
CG-36	15	13	15	11	11	14	13
CG-38	14	13	13	11	13	15	13
CG-39	13	13	10	11	8	8	8
Mean	11.29	12.14	10.14	10.00	8.71	9.86	8.71
Sc_Know							
CG-30	11	9	14	13	11	12	11
CG-31	6	11	10	9	4	6	5
CG-34	8	11	9	8	4	5	7
CG-35	12	12	6	9	5	8	7
CG-36	13	12	11	12	9	13	11
CG-38	14	12	14	13	13	12	13
CG-39	11	9	11	14	9	9	13
Mean	10.71	10.86	10.71	11.14	7.86	9.29	9.57
Sc_Proc							
CG-30	7	11	14	13	12	13	7
CG-31	7	5	8	4	7	4	4
CG-34	7	5	8	5	7	4	5
CG-35	8	8	11	7	7	9	6
CG-36	14	14	11	11	10	13	7
CG-38	9	14	14	11	13	14	9
CG-39	14	9	11	13	10	10	6
Mean	9.43	9.43	11.00	9.14	9.43	9.57	6.29

Table 30: School assessment results for the control group, Year 9

Year = 9	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Ma_Know							
CG-32	13	13	12	11	13	11	11
CG-33	14	14	14	13	15	14	14
CG-37	12	12	11	11	11	12	13
Mean	13.00	13.00	12.33	11.67	13.00	12.33	12.67
Ma_Proc							
CG-32	12	12	12	12	12	12	12
CG-33	15	14	14	11	11	13	13
CG-37	12	12	8	11	10	9	9
Mean	13.00	12.67	11.33	11.33	11.00	11.33	11.33
Sc_Know							
CG-32	11	11	9	14	11	12	10
CG-33	14	15	15	15	13	14	13
CG-37	12	13	11	13	11	11	12
Mean	12.33	13.00	11.67	14.00	11.67	12.33	11.67
Sc_Proc							
CG-32	12	12	11	10	11	11	11
CG-33	15	15	15	15	14	14	14
CG-37	14	14	11	13	13	10	6
Mean	13.67	13.67	12.33	12.67	12.67	11.67	10.33

Table 31: School assessment results for the control group, Year 10

Year = 10	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Ma_Know							
CG-10	10	12	14	9	9	6	8
CG-11	12	14	14	15	14	12	12
CG-12	9	10	7	8	9	9	9
CG-13	13	15	15	15	12	12	12
CG-14	10	11	13	14	9	7	8
CG-15	8	12	12	12	8	6	6
CG-16	11	11	10	9	11	4	9
CG-17	13	13	13	10	11	11	11
CG-18	7	9	6	6	10	6	7
CG-19	8	7	7	6	7	4	4
Mean	10.10	11.40	11.10	10.40	10.00	7.70	8.60
Ma_Proc							
CG-10	11	9	12	12	14	11	12
CG-11	13	15	15	15	14	13	13
CG-12	8	8	8	8	11	9	8
CG-13	15	14	15	15	14	12	12
CG-14	12	13	11	11	11	8	8
CG-15	9	12	8	8	8	8	8
CG-16	14	11	11	13	11	5	10
CG-17	11	11	13	9	15	15	15
CG-18	12	11	8	6	8	9	9
CG-19	10	8	8	7	9	8	8
Mean	11.50	11.20	10.90	10.40	11.50	9.80	10.30
Sc_Know							
CG-10	13	11	11	12	11	12	12
CG-11	13	13	14	13	13	13	13
CG-12	11	8	11	10	11	11	11
CG-13	13	11	14	14	14	14	14
CG-14	5	8	14	13	11	13	13
CG-15	11	8	10	12	10	11	11
CG-16	13	8	14	12	12	11	11
CG-17	13	13	14	12	14	14	14
CG-18	7	11	11	9	11	9	9
CG-19	7	8	12	11	9	9	9
Mean	10.60	9.90	12.50	11.80	11.60	11.70	11.70
Sc_Proc							
CG-10	11	11	14	12	11	12	12
CG-11	14	14	14	14	14	14	14
CG-12	14	11	11	11	11	11	11
CG-13	14	14	14	14	14	14	14
CG-14	11	14	14	13	11	13	12
CG-15	14	8	11	11	10	11	11
CG-16	14	11	14	8	12	10	10
CG-17	15	15	14	11	14	14	14
CG-18	14	14	12	8	11	9	9
CG-19	8	8	11	11	9	9	9
Mean	12.90	12.00	12.90	11.30	11.70	11.70	11.60

Table 32: School assessment results for the control group, Year 11

Year = 11	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Ma_Know							
CG-2	8	11	11	2	2	3	3
CG-20	6	14	14	2	6	1	1
CG-21	15	8	8	7	8	9	9
CG-22	9	8	8	3	5	2	4
CG-23	11	5	5	6	2	3	3
CG-24	3	3	3	6	7	1	1
CG-25	8	2	2	3	4	6	6
CG-26	13	11	11	8	9	6	13
CG-4	8	2	3	4	4	1	1
CG-5	15	11	12	8	9	8	9
CG-6	14	5	8	3	9	3	3
CG-7	13	14	13	8	8	4	4
CG-8	14	8	8	9	9	4	6
CG-9	9	9	6	4	3	1	1
Mean	10.43	7.93	8.00	5.21	6.07	3.71	4.57
Ma_Proc							
CG-2	8	8	8	5	5	5	6
CG-20	2	8	8	2	7	1	1
CG-21	9	8	8	9	8	9	9
CG-22	8	2	4	3	7	3	4
CG-23	5	7	7	2	4	2	5
CG-24	5	2	2	8	6	1	1
CG-25	5	8	7	5	3	4	5
CG-26	12	5	5	7	12	9	12
CG-4	7	6	5	7	7	5	4
CG-5	15	11	12	11	11	8	11
CG-6	5	8	8	5	8	5	5
CG-7	8	8	8	11	8	5	6
CG-8	14	10	9	10	8	2	9
CG-9	8	8	8	7	5	5	4
Mean	7.93	7.07	7.07	6.57	7.07	4.57	5.86
Sc_Know							
CG-2	8	6	7	4	6	4	4
CG-20	10	8	8	4	5	3	3
CG-21	8	8	8	9	4	2	5
CG-22	8	9	9	8	10	7	5
CG-23	8	5	5	5	6	5	5
Sc_Know							
CG-24	8	8	8	9	6	3	2
CG-25	6	5	5	5	3	4	3
CG-26	8	8	8	8	9	9	8
CG-4	8	8	8	1	2	3	3
CG-5	11	8	11	12	11	10	11

Year = 11	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
CG-6	10	9	7	6	9	6	5
CG-7	10	9	10	12	13	10	11
CG-8	11	8	9	9	5	8	7
CG-9	5	5	5	5	4	3	4
Mean	8.50	7.43	7.71	6.93	6.64	5.50	5.43
Sc_Proc							
CG-2	8	8	8	7	7	7	7
CG-20	11	8	8	7	5	5	5
CG-21	8	8	8	7	7	7	7
CG-22	8	8	8	8	8	7	8
CG-23	8	8	8	8	7	7	7
CG-24	10	8	8	7	7	7	7
CG-25	5	5	5	7	7	7	7
CG-26	8	8	8	8	8	8	8
CG-4	8	8	8	7	7	7	7
CG-5	14	8	10	12	9	11	10
CG-6	8	5	7	7	7	7	7
CG-7	8	8	8	14	14	9	11
CG-8	11	14	12	10	7	8	8
CG-9	5	5	5	7	7	7	7
Mean	8.57	7.79	7.93	8.29	7.64	7.43	7.57

Table 33: School assessment results for the control group, Year 12

Year = 12	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Year = 12							
Ma_Know							
CG-1	9	11	11	7	11	9	8
CG-27	6	5	3	6	1	4	4
CG-28	4	6	4	5	1	1	1
CG-29	2	8	7	9	7	11	11
CG-3	11	9	11	8	10	10	10
Mean	6.40	7.80	7.20	7.00	6.00	7.00	6.80
Ma_Proc							
CG-1	12	9	9	5	9	9	9
CG-27	4	8	3	4	1	4	4
CG-28	3	7	7	8	1	1	1
CG-29	2	6	8	9	6	8	8
CG-3	8	11	8	11	14	14	14
Mean	5.80	8.20	7.00	7.40	6.20	7.20	7.20
Sc_Know							
CG-1	8	6	5	5	5	4	8
CG-27	5	4	7	4	5	5	5
CG-28	4	5	3	2	5	6	6
CG-29	12	9	8	11	11	5	8
CG-3	14	13	14	14	14	14	13
Mean	8.60	7.40	7.40	7.20	8.00	6.80	8.00
Sc_Proc							
CG-1	11	8	8	7	7	6	6
CG-27	5	7	7	7	7	7	7
CG-28	7	7	7	7	7	7	7
CG-29	14	11	14	14	11	8	8
CG-3	13	14	14	11	12	12	12
Mean	10.00	9.40	10.00	9.20	8.80	8.00	8.00

Table 34: Control group school assessment means for each year level

	2002 Term 2	2002 Term 3	2002 Term 4	2003 Term 1	2003 Term 2	2003 Term 3	2003 Term 4
Year 8							
Ma_Know	11.57	10.86	11.57	11.14	11.00	8.71	10.57
Ma_Proc	11.29	12.14	10.14	10.00	8.71	9.86	8.71
Sc_Know	10.71	10.86	10.71	11.14	7.86	9.29	9.57
Sc_Proc	9.43	9.43	11.00	9.14	9.43	9.57	6.29
Year 9							
Ma_Know	13.00	13.00	12.33	11.67	13.00	12.33	12.67
Ma_Proc	13.00	12.67	11.33	11.33	11.00	11.33	11.33
Sc_Know	12.33	13.00	11.67	14.00	11.67	12.33	11.67
Sc_Proc	13.67	13.67	12.33	12.67	12.67	11.67	10.33
Year 10							
Ma_Know	10.10	11.40	11.10	10.40	10.00	7.70	8.60
Ma_Proc	11.50	11.20	10.90	10.40	11.50	9.80	10.30
Sc_Know	10.60	9.90	12.50	11.80	11.60	11.70	11.70
Sc_Proc	12.90	12.00	12.90	11.30	11.70	11.70	11.60
Year 11							
Ma_Know	10.43	7.93	8.00	5.21	6.07	3.71	4.57
Ma_Proc	7.93	7.07	7.07	6.57	7.07	4.57	5.86
Sc_Know	8.50	7.43	7.71	6.93	6.64	5.50	5.43
Sc_Proc	8.57	7.79	7.93	8.29	7.64	7.43	7.57
Year 12							
Ma_Know	6.40	7.80	7.20	7.00	6.00	7.00	6.80
Ma_Proc	5.80	8.20	7.00	7.40	6.20	7.20	7.20
Sc_Know	8.60	7.40	7.40	7.20	8.00	6.80	8.00
Sc_Proc	10.00	9.40	10.00	9.20	8.80	8.00	8.00