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DESIGN AND IMPLEMENTATION OF A COGNITIVE MEDIATED INTERVENTION PROGRAMME WITH FIRST YEAR METALLURGY STUDENTS.

by

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A Research Report submitted to the Faculty of Humanities, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Education (Educational Psychology)

Johannesburg, South Africa 2007

TABLE OF CONTENTS

ACKNOWLEDGEMENTS 6

DECLARATION 7

ABSTRACT 8

CHAPTER ONE – INTRODUCTION AND HISTORICAL BACKGROUND 9

1.1. Historical Background 9

1.2. Context of Engineering Students 10

CHAPTER TWO – LITERATURE REVIEW 15

2.1. Transition from school to university 15

2.2. Learning Approaches 16

2.3. Constructivism 19

2.4. Intelligence 20

2.5. Feuerstein's theory of Structural Cognitive Modifiability (SCM) 21

2.6. Instrumental Enrichment 23

2.7. Studies that critique the findings of Cognitive Mediation. 25

CHAPTER THREE - METHODOLOGY 28

3.1. History of the Research Programme 28

3.2. Rationale for the present study 32

3.3. Aims of the current study 33
3.3.1. General Aim 33
3.3.2. Specific aims 33

3.3. Research Questions 34

3.4. Research Design 34

3.5. Sample 35

3.6. The Measurement Instrument 35

3.7. Ethical Considerations **37**

3.8. Procedure **38**
3.8.1. Pre-tests **38**
3.8.2. Intervention **38**
3.8.3. Post-tests **39**

CHAPTER FOUR - RESULTS **41**

4.1. Overview of Data Analysis **41**

4.2. Descriptive Statistics **43**

4.3. Inferential Statistics **46**

4.4. Conclusion **48**

CHAPTER FIVE – DISCUSSION **49**

5.1. Improvement in academic performance **49**

5.2. Critical Analysis of reasons for the results in 5.1 **50**
5.2.1. Underpreparedness of the first–year students **50**
5.2.2. Underpreparedness of the curriculum **51**
5.2.3. Curriculum changes **52**
5.2.4. The problem of transfer **56**

5.3. Improvement in intellectual functioning **58**
5.3.1. Critical analysis of reasons for the results listed above. **59**
5.3.1.1. The Effect of Maturation **59**
5.3.1.2. The cognitive mediated intervention programme **59**

5.4. Possible reasons for results discrepancies **60**
5.4.1. Research findings that critique cognitive mediation **60**

5.5. Summary of the research findings **61**

CHAPTER SIX – RECOMMENDATIONS AND CONCLUSION **62**

6.1. First Recommendation **65**
6.1.2. Implications for future research **67**

6.2. Second Recommendation **67**
6.2.1. Implications for future research **69**

6.3. Limitations of the Study **69**

6.4. Conclusion **70**

7. REFERENCES **72**

8. APPENDICES **86**

Appendix A **Explanation of Adapted cognitive functions from Feuerstein's IE programme** **86**

Appendix B **Adapted Cognitive Functions for use in Engineering by Professor Skuy (2003)** **87**

Appendix C **Letter of Consent** **88**

Appendix D **Cognitive Intervention Programme (12 Week Outline)** **89**

Appendix E **Cognitive Intervention Programme for Friday 29 July 2005** **95**

Appendix F **Statgraphics Example** **98**

Appendix G **A Selection of Student Evaluations of the Cognitive Mediated Programme** **101**

Appendix H **Newspaper Article** **105**

Appendix I **The Record Sheet of the Cognitive Assessment System** **106**

TABLES AND FIGURES

List of Tables

Table 4.1.	**Kolmogorov-Smirnov Test**	**41**
Table 4.2.	**Demographic Information of the Sample**	**44**
Table 4.3.	**Mean scores on the examination results**	**45**
Table 4.4.	**Mean scores on the six subtests of the CAS**	**45**
Table 4.5.	**Results of match paired t-Tests for each CAS subtest and mid-year and end-year examinations**	**46**
Table 4.6.	**Correlations between the CAS post subtests with the end-of-year examinations (Pearson's Product Moment Correlation Coefficient = r)**	**48**

List of Figures

Figure 4.1.	**Histogram of the End-of-year examination.**	**42**
Figure 4.2.	**Scatterplot Graph**	**43**

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DECLARATION

I hereby declare that this research report is my own and unaided work. It is being submitted for the degree of Master of Education (Educational Psychology) at the University of the Witwatersrand, Johannesburg. It has not been submitted for any degree or examination at any other University.

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Kim Fairon Date

ABSTRACT

This study was conducted as part of an ongoing research programme to evaluate and implement change in the School of Process and Materials Engineering (PRME) 1002 course curriculum to effect positive results in academic achievement, thus increasing throughput rates of first-year Chemical and Metallurgical engineering students. This study designed and implemented a cognitive mediated intervention programme adapted by Professor Skuy (2003) from Feuerstein's Instrumental Enrichment (1980) programme. The aim was to see if an extended programme period of time, 12 weeks as opposed to 5 weeks implemented in an earlier study by Viviers (2004), would significantly improve the academic performance of the sample of 20 first-year Metallurgy students as measured by the mid-year and end-of-year examination results. The study also aimed to find out if the cognitive mediation intervention programme would significantly improve the intellectual functioning of the Metallurgy students. The results show that mediating cognitive functions significantly improved the intellectual functioning of the sample of 20 students as measured by the pre- and post-test scores of the Cognitive Assessment System (Das & Naglieri, 1993). However, no significant improvement was found in the academic achievement of the students as measured by the examination results. Accordingly it was concluded that the extended period of time (12 weeks), was sufficient time to improve intellectual functioning of Metallurgy students, but insufficient time for this to transfer into academic achievement for the Metallurgy students. The study highlighted the difficulty of transfer in the engineering context, as well as the continued problem that first-year students have with the complex conceptual nature and demands of the PRME (1002) course.

KEY WORDS

Underpreparedness
Mediation
Transfer
Learning Approaches
Cognitive Modifiability
Constructivism
Higher Education

CHAPTER ONE
INTRODUCTION AND HISTORICAL BACKGROUND

1.1. Historical Background

During the apartheid government era (1948-1994), education services were provided on a racially segregated basis, so that White, Black, Asian and Coloured children were taught in separate schools with different curricula (Burden, 1995). Separate government departments catered for each race group. For example, the House of Assembly was responsible for White education, and the Department of Education and Training was responsible for Black education (Skuy, 2004). Educational policies and budget allocation favoured the White population, while allocation of resources for the other race groups was provided on the basis of the perceived order of importance of the skills required in the economy, that is, Asians, Coloureds and Blacks respectively (Rushton, Skuy & Fridjhon, 2003).

This policy resulted in drastic limitations of educational provision in particular for the majority of Black learners. A limited number of schools catered for a small percentage of the Black population, with a different and inferior syllabus to that of the White population (de Villiers, 1997). The experience for most Black learners was a chronic shortage of qualified teachers; overcrowding due to the shortage of classrooms, inadequate supply of books, and poor facilities (Sidiropoulis, 1997). The most current statistics available, taken from the population census of 2001, show that, even as recently as 2000, 22% of teachers were under-qualified, 45% of schools were without electricity, and there was a shortfall of over 67,000 classrooms (South African Institute of Race Relations, 2001/2002).

The legacy of apartheid education has also resulted in continuing inequalities at the tertiary level of education, where the White minority racial group accounted for twice as many university degrees as their Black majority racial group counterparts (South African Institute of Race Relations, 2001/2002).

After the democratic elections in 1994, the government passed legislation affecting all levels of education in an attempt to address the disadvantages and unequal education experienced by the majority of its population under the apartheid regime. *White Paper 3 - A Programme for the Transformation of Higher Education (1997)* mandated that tertiary institutions' student registrations needed to reflect the diversity of the population. Thus, an attempt was made to ensure that students of all races would have the opportunity to become graduates and take their place in a transformed, more racially representative economy. The University of the Witwatersrand made a commendable effort to meet the targets for size and demographics as stated in *the National Plan for Higher Education (2001).*

In particular, the School of Process and Materials Engineering (PRME) has widened the access for first-year engineering students, so that in the year that the current study was conducted, approximately 88% of the registered students were Black (PRME, 2005). However, this has caused a different set of concerns for the School of Engineering. As previously stated, the inequalities caused by the apartheid system in education have had far-reaching implications for disadvantaged learners studying at tertiary level.

Seabi (2004) highlights the research done by Vernon (1979); and Cahan and Cohen (1989), which demonstrated that quality and length of schooling has a strong influence on intellectual development. In addition, it is argued that learning processes developed at school affect the formation of cognitive strategies needed for successful academic performance. Taylor (1993) comments that the teaching approach utilised in the apartheid era had detrimental effects on Black learners by instilling passive acceptance of authority, rather than providing students with the conceptual tools necessary for creative, critical and independent thinking.

1.2. Context of Engineering Students

To meet the entry requirements to register in the School of Engineering at the University of the Witwatersrand, a student needs to have a higher number of

prerequisite points than is necessary for most other faculties. Studies conducted by Rushton, Skuy & Fridjhon (2003); and Skuy, Rushton, Fridjhon & Seabi (2002) at the University of the Witwatersrand, demonstrated that irrespective of race group, engineering students scored significantly higher than psychology students on a non-verbal, culture-fair test of intelligence. This is in line with research conducted in the United States, which found that engineering student scores on the scholastic aptitude tests (SAT) was one standard deviation above the SAT scores of psychology and education students (Educational Testing Service 1998). Both South African and American studies have found, however, that the attrition rate of engineering students, has been historically and continues to be, higher than that of students in other faculties (Astin & Alexander, 1993; Behr, 1982; Moller-Wong & Eide, 1997; Smith, 2002 and Woollacott, 2003,b). A marked difference found between the high attrition rate of engineering students in America compared to that of South Africa is that most students who are underprepared and drop out in the United States come from minority communities; whereas the underprepared students, who fail in South Africa, are largely from the Black majority population group (de Villiers, 1996; Lakes & Fraas, 1990).

Thus, in South Africa it is the majority population group, and not the minority population group of students, who have been educationally and socially disadvantaged. Consequently, they are at risk when they enter existing higher education programmes. In particular, students from rural and township schools still reflect the educational and social legacy of the apartheid past (Daniel, 1993; Hartshorne, 1992; Van Tonder, 1996).

As greater numbers of previously disadvantaged learners enrol as students at tertiary institutions, many of these students fail and are forced to drop out as a result of underpreparedness, due to a number of factors, including apartheid. Consequently, the attrition rates are increasing and the throughput numbers of Black graduates are in jeopardy (Seabi, 2004). This will ultimately affect the employment equity quota that the government is in the process of implementing across all sectors of the South African economy (SAUVCA, 2003). Seabi (2004) aptly comments that it is, therefore, important to explore a model that addresses the

divergent needs of students from historically disadvantaged communities and schools with a curriculum that is responsive to the issue of student diversity.

Yeld comments that incoming students to South African higher education institutions have been recognised as having very low levels of preparation. However, she remarks that there has been relatively little systematic academic development work in respect of foundation and bridging programmes. She emphasises that it is essential that, until schooling improves, higher education institutions "address the needs of the incoming students responsibly through the provision of a range of curricula that is appropriate in terms of content, pace and level" (2003, p. 46).

The School of Process and Materials Engineering (PRME), now called the School of Chemical and Metallurgical Engineering at the University of the Witwatersrand, has been acutely aware since the late 1980's that engineering students entering the programme displayed a wide diversity of ability, language, culture, expectations and preparedness for the degree course. Consequently, the statistics for graduation and throughput were low; attrition rates were high and class aggregate averages were lower than they could or should be.

The Faculty of Engineering and the Built Environment at the University of the Witwatersrand, and specifically the School of Process and Metallurgical Engineering (PRME) have provided, since 1988, various support programmes to address the entry needs of disadvantaged students (Woollacott & Snell, 2004a; 2004b). These programmes were in the format of 'add on' measures that supplemented the existing course while the curriculum itself remained essentially unchanged. By the end of 2000, it became apparent to the PRME first-year course co-ordinator, that fundamental transformation and change would need to be implemented in the mainstream curriculum programme to address the problem of underpreparedness and rates of attrition in the first-year course.

Woollacott & Snell (2004 a, b) define underpreparedness as the condition where the knowledge and competencies of the learner entering an educational programme compared negatively with the assumed knowledge and competencies on which that

programme is based. They comment that underpreparedness carries with it the implication that the students' innate abilities may be masked by significant gaps in knowledge, skills and academic deficiencies; that they are likely to perform below their potential and, in a significant number of cases, will fail when they have the ability to pass. Thus, from 2001 to 2003, the school of PRME in association/collaboration with the Cognitive Research Unit of the then Division of Specialised Education, conducted a research pilot study. The aim of the pilot study was to change the course PRME (1002) in a developmental manner by trialling potentially useful educational measures to gain a body of experience in implementation of such measures and so obtain deep insight into the nature of issues being addressed.

The theoretical framework that the pilot project used as a platform to initiate the changes in the curriculum was drawn from a number of current learning and educational theories. These included:

- Constructivism - the theory that knowledge is constructed and not received (Piaget, 1950, 1960, 1972; Papert, 1996; Vygotsky, 1962, 1978 a, b; 1988 and Jaworsky, 1997).

- The theory that intellectual ability is not static, but modifiable through appropriate learning experiences (Feuerstein & Feuerstein, 1991; Haywood & Switzky, 1992).

- The concept that learning is mediated and that the quality of cognitive enrichment is determined by the quality of the individual and group mediation (Feuerstein & Feuerstein, 1991; Kozulin & Rand, 2000).

The pilot study incorporated, adapted and refined the course on an annual basis, utilising the theories and derived practices listed above, amongst others. Elements in the curriculum that were successful were retained, and those less successful were adapted or discarded. This study is a continuation of the original pilot study with the particular aim to determine whether an extended cognitive mediation

programme can improve the academic results of first-year Metallurgy students and in so doing, address the high attrition rates in this first-year course. This is elaborated on in greater detail in Chapter Three, when the nature and rationale of the researcher's study is explicated and the specific reasons for the study are described.

CHAPTER TWO
LITERATURE REVIEW

This chapter reviews the theoretical framework of the learning approaches, cognitive modifiability, learning and mediation theories that have been used both in the pilot study and the current study. Included in this literature review are reviews of empirical studies conducted both locally and internationally that have used these theories and the results of the research findings.

2.1. Transition from school to university

Some of the literature reviewed suggests that, historically, the transition, in many countries, from secondary school to tertiary higher education has not been easy, as this is a change from one type of learning culture to another (Hines, 2005; Johnston, 1994; Lowe & Cook, 2003; Ozga & Surhnandan, 1998). In high school classroom sizes are relatively small (30-45 learners) when compared with a first-year university lecture hall of 300-450 students. Individual attention is limited and the monitoring process provided by the teacher at school changes to the paradigm in which students monitor themselves and self-evaluate how they are coping with their assignments and tests. If university students are struggling with meeting the academic demands of their programme, it is their responsibility to seek help and assistance from tutors and lecturers (Todd, 2002).

There is also a difference in learning approaches applied at secondary schools and tertiary institutions. In many high schools the passive learning approach is adopted where teachers provide the information to the students in the form of lessons and notes. The mastery of the subject content is product driven, in that the tests and examinations measure whether the learner can ‘regurgitate’ the information received. In Higher learning institutions the learning is process orientated, where students are encouraged to become active participants, engaging in debate with their lecturers on the content of the course. They are also required to demonstrate conceptual understanding and the application of knowledge in the writing of their

own notes; as well as in their tests, examinations or assignments (Cliff, 1995; Kozulin & Rand, 2000).

2.2. Learning Approaches

The difference between these two learning approaches: passive and process, was highlighted in studies conducted in the late 1970s by Marton and Saljo (1976 a, b). Their research investigated the processing of information by university students, focusing on what was learnt; rather than previous studies in cognitive psychology, which had emphasised how much was learnt. Their findings revealed two different kinds of approaches to learning, which they defined as surface (passive) and deep (process) approaches. The surface approach involved trying to memorize as much content as possible, with little attention given to understanding of the text. In contrast, the deep approach students aimed to grasp the underlying meaning of the text. These findings were replicated and endorsed in research done by Entwistle and Ramsden (1983), which designed the Approaches to the Studying Inventory (ASI). From this research they formulated four study orientations, of which the orientations of meaning and reproducing correspond to the deep and surface approaches to learning (Case & Gunstone, 2003).

Research by Meyer, Dunne and Sass (1992) on a sample of educationally disadvantaged first-year engineering students at the University of Cape Town (UCT), revealed that educationally disadvantaged students enter university with multiple disadvantages. The reasons are that, not only have they come from impoverished secondary school backgrounds, but in addition, they appear to have adopted surface approaches to their study of school science. Cliff argues that the surface approach is “a sterile, minimalist engagement with the subject content and a focus on reproducing this content to meet perceived assessment demands” (1995, p. 171).

What is of real interest is that similar studies done by Meyer and Sass, but using a sample of engineering students **not** from educationally disadvantaged backgrounds,

revealed qualitative evidence of “spirals of deteriorating study behaviour, in the transition between school and university study, for all first-year students” (Cliff, 1995, p. 171).

Cliff’s research on subsets of students from both advantaged and disadvantaged backgrounds (1995) corroborated the earlier findings by Meyer and Sass (1993), and Meyer (1994). These showed that school-based study behaviour placed students “at risk” on entry to university and supported the premise that this is not a phenomenon associated only with a particular student sample (Cliff, 1995, p. 179).

The UCT Engineering Department conducted further studies on a group of second year Chemical Engineering students (Case, 2000); and continued to research engineering students’ learning behaviours as part of an ongoing study (Case & Gunstone, 2003). Their findings demonstrated that many of the students in the Chemical Engineering courses used the algorithmic and the information-based learning approaches in assimilating the course material and in assessment. They define these approaches in the context of the Chemical Engineering course (CHE 251 F) in the following manner. The intention of the algorithmic approach is to remember calculation methods for solving problems; and that of the information-based approach is to remember information that can be supplied in response to assessment questions. Both these approaches may be considered surface in comparison to the deep approach of the third category, viz. the conceptual approach. The intention of this approach is to understand concepts (Case, et al., 2003, p. 806).

Many of the Chemical Engineering students had successfully used the algorithmic and information-based approaches, with good results at school (Case, 2000). However, when utilised at tertiary education level in the Chemical Engineering course, these approaches did not foster real understanding, and consequently, left students feeling that the approaches were not working and that their understanding of the material was compromised. In contrast, students who utilised the conceptual approach:

> “displayed a fundamental understanding of the purpose of the concepts, showed evidence of having puzzled over difficult concepts, and often made

> links with both prior knowledge and other subjects that were being taken concurrently. They used their own words to explain concepts and displayed a sense of confidence and security with their understanding" (Case, et al., 2003, p. 807).

As a result of these findings, the Chemical Engineering course at UCT (CHE 251F) was redesigned and restructured to foster the conceptual learning approach to be used by students from the beginning of the course. This was done, as it was found that it was very difficult for students to change successfully from the algorithmic and information-based approaches, to the conceptual approach, further along in their studies. It was also discovered that the surface approaches did not foster understanding and hence negatively affected academic results (Case, et al., 2003).

Overseas studies have produced similar results to those of southern African universities (Gamache, 2002; Lowe & Cook, 2003; Power, Robertson & Baker, 1987; Yorke, 1998). A review of research studies from a number of different United Kingdom universities that formed part of a project, was conducted by Entwistle, McCune & Hounsell (2002). The name of the project was 'Enhancing teaching–learning environments in undergraduate courses' or ETL. This project, in the United Kingdom, aimed to foster deep approaches to learning and conceptual understanding in university courses. Their goal was to re-educate students who had entrenched study habits that were inappropriate for higher education. The ETL project focus has been to encourage greater engagement of students in their studies, and so promote higher quality of learning. The research findings reveal that the tutoring of students, over a number of years in a supportive environment, is the most successful method of changing negative, entrenched study/learning behaviours.

Over a decade ago in the United States, Perkins (1993) identified the need for the secondary education system to teach for understanding so that the students would proceed beyond rote learning and then use their understanding to predict outcomes and generalize that understanding to other areas of life and learning. This would in turn help students to study more effectively at tertiary education level and cope productively and practically in their chosen profession. Perkins named this

“performance perspective” in terms of understanding and reflected that this perspective was based on the theory of constructivism prominent in contemporary theories of learning (1993, p. 4).

2.3. Constructivism

Gravett (2001) comments that the term constructivism is used to denote a cluster of related views that all rest on the assumption that learning is an active process of constructing knowledge or meaning and transforming understandings in interaction with the environment. The acknowledged historical father of constructivism is Piaget (1968) who posited that people, from birth, actively and continuously organise and re–organise information and experiences so that they can adapt to the world in progressively more effective ways. Piaget’s view is that knowledge is constructed through cognitive conflict, which he termed disequilibration. This sense of disequilibration is caused by the perception of new information that is in contrast to the existing knowledge in the schemata of the person. As a result, the cognitive structure of the individual either assimilates (process through which existing structures are maintained, but new information is taken in) or accommodates (process of re-organisation of existing structures) the new information in order to resolve the cognitive conflict.

Vygotsky (1978 a, b) disagreed with Piaget’s view that knowledge is constructed independently. In contrast, Vygotsky posited that social interactions with more mature and knowledgeable thinkers fosters knowledge construction through the transmission of values, information and understanding. Vygotsky (1978 a, b) defines the critical space between the learner and the more mature thinker as the Zone of Proximal Development (ZPD). Vygotsky’s concept of the ZPD portrays the learner as actively constructing knowledge with the help of a mediator through social interaction processes. The term scaffolding was introduced by Bruner (1977) to denote the overarching framework upon which knowledge can be co-constructed by the learner and mediator. This provision of a structural framework functions similarly to the boundary pieces and box picture of a puzzle: the learner has a sense

of what is required but still needs to actively work out, using their intellectual ability, what information (puzzle pieces) fit where. The mediator provides help and suggestions but gradually withdraws as the learner reaches a level of constructing his/her own internalised understanding (Bruner, 1977). The ability to actively construct knowledge can be viewed as an intellectual exercise that is dependent on intellectual ability or intelligence.

2.4. Intelligence

One of the controversial issues in the field of psychology has been how intelligence is defined and what factors affect it. A fundamental question that remains at the centre of the debate is whether intelligence is static or modifiable? Feuerstein defined human intelligence as the accessibility and potential of the human being to modify his interaction in response to the environment (Feuerstein, Rand & Hoffman, 1979). Piaget (1950) had a significant influence on Feuerstein's understanding of cognitive processes. Piaget viewed intelligence as a process that helped the individual adapt to his environment. Piaget’s work focused on stimulus, organism and response (S-0-R), which involved an individual responding to the stimuli. Accordingly, an individual learns from direct interaction with the environment. Feuerstein extended the work of Piaget by adding the human factor to the equation, in which a mediator is interposed between the stimulus and organism, that is S-H-O-R.

Feuerstein's theory of Structural Cognitive Modifiability (SCM) is based on an optimistic and humanistic view of an individual's potential to change and adapt to his environment (Lebeer & Roth, 2001). Thus, central to SCM is the notion that the concept of intelligence is dynamic and capable of change. Feuerstein rejected the idea that individuals have an inherent intelligence level that remains static and fixed for life. He believed in the autoplasticity of the brain; meaning that humans are able to modify themselves, respond and adapt to changes in both the internal and external environment. He described two approaches to understanding intellectual functioning: the passive-acceptance approach and the active-

modification approach. The former approach views the individual as a closed organism, who is unable to change, whose poor performance is due to genetic or organic factors. However, Feuerstein subscribes to the active-modification approach which views the individual as an autoplastic system, open to change, who by utilising information can cope with new tasks, modify cognitive functions and is able to learn from experience (Feuerstein, Rand, Hoffman & Miller, 1980).

Robert Sternberg (1982) reviewed a number of studies on varied approaches to the training of intelligent performance. These studies demonstrated that intelligence, when viewed as an information-processing construct, could be modified through the training of information skills. A few years later Sternberg posited his Triarchic theory of intelligence (1985) which was different to the traditional theoretical perspectives (Murphy & Maree, 2006). Sternberg's theory focused on three aspects of intelligent behaviour: context, experience and information processing skills. He emphasised that if an individual wanted to assess the intelligence of a person, he/she needed to consider firstly, the context of performance. Secondly, a person's experience with a task helps to determine whether his/her performance qualifies as intelligent behaviour. Thirdly, Sternberg believed that intelligence is fluid and could change as the brain adapts. Perkins (2002) comments that many psychologists have come to change their understanding that intelligence is innate and static and ‘come to the conclusion that intelligence is to a substantial degree, learnable’ (2002, p.1).

2.5. Feuerstein's theory of Structural Cognitive Modifiability (SCM)

Feuerstein, et al. (1979) investigated the cognitive functioning of individuals exposed to conditions of deprivation similar to those of apartheid and demonstrated that these individuals experienced cognitive deficiencies as a result. Feuerstein theorised that parents help their children make sense of the world through mediated learning experiences. In the case of cultural or socio-economic deprivation, parents may be unable to help their children understand the environment and thus fail to

enable their children to engage independently and autonomously with stimuli. This results in impairment to intellectual functioning.

The theory of SCM suggests that irrespective of environmental factors, such as poverty, low socio-economic status, socio-political deprivation or genetic heritability, it is possible to modify the cognitive structures of the individual. Feuerstein's model of Mediating Learning Experiences (MLE), which takes into account, not only the experiences the learner has acquired, but also his/her potential to learn, is one that has been used successfully with children but is claimed to be applicable to all individuals of different race and age groups (Feuerstein, et al., 1980). It is viewed as an intervention that successfully helps disadvantaged learners to bridge the gap between their past experiences and the academic, creative and practical demands of their current academic courses.

Studies conducted by Feuerstein, Rand and Rynders (1988) using MLE show that this model is significant in developing thinking skills that relate to problem solving, creativity and conceptualisation. These are skills deemed to be essential for students studying engineering (Skuy, 2003). The framework of this study is based on Feuerstein's construct of MLE (Feuerstein, et al., 1979), although Vygotsky's theory (Vygotsky, 1978 a, b) is also taken into account. There are some areas of convergence between these perspectives, the most obvious being that of the process of mediation. In Vygotsky’s theory mediation is the ‘engine’ that drives development. To mediate means to intervene intentionally, but not direct the process. Cognitive mediation involves helping a learner, through proximal interactions (problem solving under guidance), to construct a new level of understanding.

According to Vygotsky (1978 a, b), knowledge is constantly evolving as a result of social construction and reconstruction. Knowledge cannot be taught as if it was static and unchanging. The theories of Vygotsky (1978 a, b) and Feuerstein, et al., (1979) are considered the most comprehensive theories of mediated learning. The underlying assumption of both theories is that competence is modifiable or can be improved.

What is taught and what is learned cannot be separated from the social context as students bring knowledge, skills, views and understanding to the teaching/learning situation from their own particular social contexts and reference worlds. Donald, Lazarus and Lolwana (2002) stated that one of Vygotsky's main contributions has been in helping us to understand how language (written language, spoken language, mathematical language and other symbolic systems) develops as a tool of cognitive development. His theory is an attempt to explain cognitive development as the end product of socialisation. He states that the learner's potential for cognitive development depends upon the zone for proximal development (ZPD). The ZPD is the distance between the actual developmental level, as determined by independent problem solving, and the level of potential, as determined through problem solving under mediation. Thus, the range of skill that can be developed with mediation exceeds what can be attained alone (Rozycki & Goldfarb, 2000).

2.6. Instrumental Enrichment

Feuerstein, et al. (1979) elaborated on Vygotsky's theory (1978 a, b) to develop his Instrumental Enrichment (IE) programme as a strategy for learning to learn (Skuy, 1993). IE uses abstract, content-free, organisational, spatial, temporal and perceptual exercises that involve a wide range of mental operations and thought processes. Feuerstein developed the concept of Instrumental Enrichment to complement and provide the implementation model for the Mediated Learning Experience (Feuerstein, et al., 1980). He explains that the main goal of Instrumental Enrichment, consonant with the theory of Structural Cognitive Modifiability, is to promote the propensity to learn and to facilitate the process of intellectual modification by means of the learning activities. Instrumental Enrichment does not focus on increasing the repertoire of knowledge of the individual, although Feuerstein notes wryly that this will happen. Instead, the emphasis is on enabling the student to learn how to acquire more information and to work out what to do with it. Its aim is also to make the learner more efficient in his efforts to acquire new skills, and to enable him to find adaptive ways to solve problems. Feuerstein, Rand & Rynders (1988) comment that this is what makes

Instrumental Enrichment different from programmes that orientate the teaching efforts towards the acquisition of specific cognitive skills or adaptive behaviours. “The difference is akin to giving someone fish each day, or giving him the necessary equipment, knowledge and skills to enable him to catch his own fish whenever he needs to or wants to” (Feuerstein, et al., 1988, p. 211).

The aim of Feuerstein's Instrumental Enrichment programme is to change the overall cognitive structure of the (impaired) learner by transforming his passive and dependent cognitive style into that of an independent thinker.

Feuerstein divides cognitive functions into three phases of a mental act: input, elaboration and output. Input is the first phase of the behaviour in which information is gathered about the problem to be solved. Secondly, in the elaboration phase, information gathered at the input level is processed. The third phase is called the output phase. This is where the individual has to emit his response, the product of his elaboration of the data gathered initially. Instrumental enrichment is designed through the use of learners interacting with the 14 instruments (clusters of exercises) to teach the individual to constantly project relations between things, or relations of identity, similarity, opposition or incompatibility. The student is mobilised to become an active perceiver and organiser of his experience (Feuerstein, et al., 1988).

The technique of IE has been used in numerous studies both in South Africa and abroad (Haywood, 1988; Nell, 2000; Skuy, Archer & Roth, 1987; Skuy, Mentis, Arnott & Nkwe, 1990; Skuy & Schmukler, 1987) and the evidence suggests its value for improving the intellectual functioning of disadvantaged students. Cotton (n/d, 2005) reviewed 56 studies that researched the teaching of thinking skills. She comments that a large majority of the studies endorse the findings that teaching thinking skills results in students becoming effective thinkers, which in turn has a positive effect on the achievement levels of the participating students.

2.7. Studies that critique the findings of Cognitive Mediation.

It is interesting to note that in the review by Cotton (n/d, 2005), there is no exact number or percentage given to the studies that found that thinking skills instruction did not enhance academic achievement. Nigel Blagg (1991) is not so vague in his evaluation of the efficacy of programmes to change cognitive abilities and enhance intellectual functioning and performance. He alludes to the work of Bradley (1983) as a detailed, penetrating and critical review of the status of Feuerstein's ideas (1991, p. 25). Bradley comments that in his interviews with researchers who had conducted studies on cognitive modification and its impact on intellectual performance, a general response was that "the results while modest, are promising" (1983, p. 83). Blagg (1991) asserts that subsequent research in this area, confirmed that on close scrutiny, many of the studies demonstrated methodological flaws and over-optimistic interpretations. Much of the research he reviewed contained confounding variables, which could have positively affected the results. Research by Shayer and Beasly (1987) focused on the American and Israeli Instrumental Enrichment (IE) studies, the data of which they meta-analysed. Their findings again "show only moderate gains on the intelligent test items closely related to the IE programme and very limited and modest gains on certain achievement measures" (cited in Blagg, 1991, p. 26). A recent meta-analysis of the impact of Feuerstein's Instrumental Enrichment (IE) by Romney and Samuels (2001) evaluated 40 controlled studies comprising 47 different samples. They too describe their findings as "significant, though modest" (cited in Wegerif, 2002, p.19).

In a review of South African research in the field of dynamic assessment in higher education, Murphy and Maree (2006) define dynamic assessment as a sequence of a pre-test followed by mediation and concluding with a post-test. Murphy and Maree (2006) review a number of studies carried out in South Africa and give feedback on both the positive and negative results of the research conducted. Their findings conclude that 72% of the studies are positive, while 7% are negative in terms of dynamic assessment being able to predict performance to the same degree as or better than conventional tests. However, what is really interesting is that both Gaydon (1988) and Schochet (1986) found that the degree to which students'

performance is modifiable will not necessarily predict or constitute academic success.

In 1983, in the United Kingdom, the Somerset Local Education Authority obtained funding for a five-year project to trial the application of IE to 14–16 year old low-achieving adolescents. Evaluation of the programme revealed, "there were problems with transfer and generalization that seemed to be related to the 'content free' nature of IE" (Blagg, 1991, p. 142). According to Greeno, Collins & Resnick (1996), transfer can be defined as the process of applying knowledge in new situations or contexts. Blagg comments that the problems with transfer, found in the afore-mentioned study, raise the issue of whether it is possible to teach transferable skills independent of particular domains. His concern was echoed by other educational psychologists who were arguing "that learning is situated in contexts and is about participation in communities of practice" (Rogoff, Gauvain & Ellis, 1991, p. 315). Hennesy, McCormick & Murphy (1993) posited that thinking skills are embedded in cultural tool systems, that is, what is learned in the context of one cultural task could only be assumed to relate to that task. Consequently, for many psychologists and educators the implication was that teaching for transfer from one context to another, was not possible.

Annett (1989) disagreed and suggested that perhaps the key to transfer lay in the teaching of higher-level executive processes rather than the lower-order components skills as described in Bloom's taxonomy. Salomon and Perkins (1989) echoed this idea and defined two distinct but related mechanisms: *low road* and *high road* transfer. They explain, "*low road* transfer is what happens when the stimulus conditions in the transfer context are sufficiently similar to those in a prior context of learning to trigger well-developed semi-automatic responses. In contrast, *high road* transfer, depends on mindful extraction from the context of learning or application and a deliberate search for connections" (Perkins & Salomon, 1992, 2005).

The researcher duly noted these critiques of, and insights into, the problems that have been found in evaluation of mediated cognitive programmes. The intention of the study was to create an adapted IE programme that would focus on the context

of engineering, as well as attempt to target the higher-level executive processes of the students, that is, *high road* transfer in order to facilitate improvement of academic performance in the PRME course examination results.

CHAPTER THREE
METHODOLOGY

3.1. History of the Research Programme

The exploratory educational pilot programme in the School of Process and Materials Engineering (PRME) was implemented in 2001 to address the issues of attrition, access and academic underperformance in first-year Chemical and Metallurgical engineering students.

The thinking was to change from supplementary measures to the existing traditional programme or extending the length of the first-year course, to redesigning various elements of the mainstream curriculum. The major changes involved creating a more active and collaborative learning environment and promoting group work. The number of lectures given in a lecture format in a theatre environment was reduced to one hour a week and the rest of the contact time was spent in a flat-floored venue with students divided into set groups of three or four students. Tutors utilised reflective and qualitative performance measures/measurements, as opposed to the traditional emphasis on quantitative problems and measures, in assessing assignments and tests. The weighting of the final examination was also reduced and greater emphasis was placed on coursework assessment with intensive feedback (Woollacott & Henning, 2004).

The theoretical framework for the curriculum change was based on Piaget's constructivist position in which the primary tool of learning is self-discovery. This is best fostered by providing an active learning environment in which students can participate and engage with learning tasks (Woollacott & Snell, 2004 a, b).

However, evaluation of the pilot study at the end of 2001 revealed that the curriculum and mode of delivery changes did not have a positive effect on the year-end academic results of the PRME course. The evaluation indicated that a number of factors seem to have contributed to these results. There were two factors that

appeared to have the greatest impact. The first was that the disparity between the learning environment in PRME 1002 and that of the other 'core' courses in first-year was detrimental as the courses of Physics, Mathematics and Chemistry were lectured and assessed in a very similar way to the students' experiences of these subjects in secondary school. Secondly, due to the newness of the course, the course-co-ordinator was overwhelmed by the students' needs in the course and was thus unable to interact and give feedback as frequently as needed, or as intensively as was required. It was also noted that the gap between the students' prior knowledge and the intellectual content of the course was so enormous that they could not make the accommodation (in a Piagetian sense) necessary to assimilate the new knowledge, even in an environment conducive to self-discovery and participatory learning (Woollacott, et al., 2004).

This resulted in a more mediated learning environment being fostered in the curriculum. This was based on Bruner's (1977) concept of scaffolding as mentioned in the literature review. In 2001, Dr. Pinto developed the Victor Problem Solving method to aid students in their methodology of tackling difficult engineering calculations. Mr. Woollacott subsequently included this method in the PRME (1002) course. Victor is an acronym for important elements of the problem solving process in an academic environment. The six elements of the process are:

- **V**isualize the situation (draw a diagram)
- **I**nterpret the information (analyse the information carefully)
- **C**larify the problem (what is given, required or relevant)
- **T**ackle the problem (by finding effective solution strategies)
- **O**rganise (how you present the solution)
- **R**eview the solution

(PRME 1002 Course Manual, 2003 a: 118-125)

Peer group mentoring and an increase in the number of tutors available for each group, as well as the employment of a full-time teaching assistant were methods used to undergird the mediation process. Thus, the focus in 2002 was on increasing

the effectiveness of the tutoring system, implementation of a marking intensive feedback system, utilising the tutors, and fostering group learning approaches. The review process of the second year of the pilot study (2002) revealed that despite the more interactive and feedback learning approach being used, the students were still having difficulty mastering the Victor problem solving methodology. At the beginning of 2003, Professor Skuy and the Cognitive Research Unit joined the research team and collaborated with the school of PRME in the pilot project. In his analysis and evaluation of the previous year's programme, Professor Skuy concluded that the difficulty that the students had in mastering the problem solving process and speed of task execution, related directly to the various cognitive functions that were required to be utilised and mastered in order for problem solving to take place (Woollacott, et al., 2004 a, b). The Victor method and its elements fall into three major categories of cognitive functions, as defined by Feuerstein and subsequently adapted by Professor Skuy (2003). (This is explained in Appendix A).

The significance of these observations was that the struggle that some students had with problem solving was perhaps rooted in difficulties in elements of their cognitive functioning. This suggested that the pilot study required a shift in focus, concerning the curriculum. The goal was to develop and mediate students' cognitive functions, rather than to concentrate on improving their problem solving skills and other academic competencies.

This resulted in experimenting with and evaluating various methods to improve cognitive functioning, based on Feuerstein's principles and adapted by Professor Skuy (2003). The principles were trialled at various levels in whole class contexts ('mass mediation'), group contexts ('group mediation'), and at the level of the individual (one-on-one interaction in teaching). Research was conducted to test the effectiveness of these mediation measures and evaluate their results.

Included in this research was a twin study conducted by Seabi (2004), and Viviers (2004), under the auspices of the Cognitive Research Unit (and the then Discipline of Specialised Education). The twin study investigated the effectiveness of Feuerstein's theory of Structural Cognitive Modifiability (SCM) and its construct

of mediated learning experiences (MLE) for enhancing intellectual functioning and academic achievement of first-year Chemical and Metallurgical Engineering students.

Seabi's study (2004) focused on a five-week MLE mediation intervention programme with an experimental group of 45 students. These students had been randomly selected from the first-year group of students, whose mid-year examination results revealed passing or above average grades. Viviers (2004) researched and developed a cognitive intervention programme, adapted from Feuerstein's Instrumental Enrichment Programme (1980), which was given to a group of 15 borderline students from the same first-year class.

These borderline students had failed the mid-year examinations with aggregate marks in the range of 40-50%, but had the potential to pass. This group also received the same MLE mediation as Seabi's experimental group. The additional cognitive intervention programme for the borderline students aimed to mediate learning strategies to enable the students to solve problems within an engineering context, as well as to mediate metacognitive operations, in order to increase students learning effectiveness.

Seabi's study (2004) showed a significant improvement in academic functioning of the group who received mediation, as measured by the post-test cognitive battery and the year-end examinations, compared to the group of students who did not receive mediation. However, no significant improvement in academic functioning could be seen in the group of borderline students who had received both the mediation and cognitive learning strategy programme. The conclusion reached, was that five weeks was sufficient time for mediation to make a difference in first-year Chemical engineering and Metallurgy students who had average or above average academic results. However, the five-week programme was an insufficient period to make a significant difference for the academically weaker students in the borderline group.

3.2. Rationale for the present study

The current researcher examined the data and the conclusions of the twin study and posited possible reasons for the discrepant findings. It may be argued that because the sample used in Seabi's study (2004) comprised of average-to-good academic students as compared with Viviers's sample (2004) of borderline/failing students, the results could be a reflection of their academic ability, rather than the success or failure of the mediation intervention. In other words, the academically average-to-good students would possibly have improved in their academic performance at the end of the year by virtue of intellectual maturity and successful adaptation over the duration of the course. In contrast, the fact that the borderline/failing students were struggling to pass the course by mid-year, may indicate that they were not, at this stage, intellectually able to cope with the course content. Thus, the mediation would logically be less effective, as they would battle to transfer learnt cognitive functions into an engineering medium that they did not really understand and thus could not master.

Therefore, the research programme needed to conduct a study that would investigate whether an extended cognitive intervention programme of 12 weeks, as opposed to 5 weeks, adapted for engineering by Professor Skuy (2003) from Feuerstein's Instrumental Enrichment programme (1980), would enhance the academic performance of academically weaker students.

The study consisted of the entire group of first-year Metallurgy students (n = 20). Historically, the Metallurgy students have entered the first-year course with a lower point average than the Chemical engineering students, resulting in higher attrition rates at the end of first-year. The perception in the School of PRME is that the Metallurgy students are "less academically able" than their Chemical engineering counterparts, with whom they share the common first-year introductory engineering courses (PRME 1002). On average the Metallurgy students' entry points were 10% lower than the entry points of the Chemical engineering students (PRME intake information, 2005).

The intervention programme was designed in such a manner as to include the assistance of a qualified engineer, who was employed as a junior lecturer by the School of PRME and who was concurrently studying for a Masters in Education in the field of engineering. Hereafter this person shall be referred to as the Junior Lecturer. The aim was for her to facilitate transfer of the cognitive functions mediated, directly into an engineering medium using relevant engineering problem exercises. The rationale was to assess whether there was any improvement in the academic performance of the students as a result of directly transferring each mediated cognitive function and applying it to an engineering context.

3.3. Aims of the current study

3.3.1. General Aim

The main aim of the study is to investigate if an extended period of mediated learning, a duration more approximate to the period of time used in comparative international studies, makes a significant difference to the academic performance and passing rates of first-year Metallurgy students.

3.3.2. Specific aims

a) To develop an extended programme of intervention mediating cognitive functions based on Skuy's adapted version of Feuerstein's Instrumental Enrichment programme.
b) To evaluate the effectiveness of this programme in improving the cognitive functions and intellectual functioning of Metallurgy students.
c) To assess whether there is a significant improvement in academic achievement as a result of student participation in this programme.

3.3. Research Questions

These aims are operationalised as the following research questions:

1) Will first-year Metallurgical engineering students' academic performance, as measured by the mid-year and end-of-year examination results, improve as a consequence of their participation in an extended mediated cognitive intervention programme?
2) Will the intervention programme significantly improve intellectual functioning of first-year Metallurgical engineering students, as measured by the difference between pre- and post-test results of the Cognitive Assessment System?

3.4. Research Design

The study was conducted as a quantitative pre-experimental research design using one group with a pre- and post-test design (McBurney, 2001).

The participants thus served as their own control, as comparisons were made before and after the intervention. In this approach, the assumption is made that the differences occurring between the pre-and post-tests are due to the effect of intervention. The researcher does acknowledge McBurney's concerns about the shortcomings of this approach with regards to the limitation of internal validity (2001, p. 269). For example, the differences between the pre- and post-tests could be as a result of extraneous variables such as maturation or the Hawthorne effect. The Hawthorne effect is when participants in the research are aware that they are part of a study and so behave differently to the way they would normally. (McBurney, 2001, p. 177). If a control group had been included in the research, the internal validity of the design would not have been limited by the possible threat of extraneous variables confounding the results. However, for ethical reasons this was not done. The researcher, in consultation with the PRME course co-ordinator considered the use of a control group, that is, half of the first-year Metallurgy class,

to be ineffective and unfair for two reasons. Firstly, it would make the sample studied very small, that is, only ten students. This would have compromised the statistical validity of the results. Secondly, it would be unethical to grant only half the historically weaker students in the PRME course, access to an intervention programme, that was hoped would improve their academic performance. Consequently, the research design of the one group pre-and post-test was agreed upon.

3.5. Sample

The sample consisted of the entire class of the first-year Metallurgy students in the PRME class of 2005 at the University of the Witwatersrand. The total class size was 20 students. The sample comprised of 5 females and 15 males. It consisted of three racial groups, namely, Whites (n = 1), Asians (n = 3) and Blacks (n = 16). Their ages ranged from 17-26 years. Nineteen of the students in this group came from previously disadvantaged backgrounds.

3.6. The Measurement Instrument

The Cognitive Assessment System (Das & Naglieri, 1993) was the measurement instrument used to gauge whether the adapted Instrumental Enrichment (IE) intervention programme improved intellectual functioning, as measured by the difference in scores between pre- and post-test administration of the Cognitive Assessment System.

The Cognitive Assessment System (Das & Naglieri, 1993)

The Cognitive Assessment System (1993), (CAS) was designed by Das and Naglieri. They proposed that intelligence is better viewed as cognitive processes that are dynamic and can change, rather than static, fixed abilities. Their work was based on the neuropsychological work of Luria (1966, 1973) as well as the

cognitive psychological findings and propositions of Broadbent (1958); Hunt & Landsmen (1986) and Simon (1981) as cited in Das, Naglieri and Kirby (1994, p. 12).

Luria (1966, 1973), like Feuerstein, et al. (1979), viewed the brain as an autoplastic system, able to change and adapt to the environment. He defined human cognitive processing as consisting of three functional systems or units that work together for mental activity to take place. The first functional unit is responsible for regulating cortical tone and maintenance of attention; the second unit receives, processes and stores information using simultaneous and successive coding; and the third unit programmes, regulates and directs mental activity (Das, et al; 1994). Utilising this conceptual framework, Das and Naglieri devised a model of cognitive functioning called the PASS model: planning, attention, simultaneous and successive (PASS) processing. The relationship between the theoretical perspectives of Luria and Das and Naglieri's work is clearly illustrated in the PASS model which takes specific brain functions of different areas of the cortex, that is, arousal, receiving and processing information and planning; and links them to the cognitive processes of attention, simultaneous and successive processing and planning. The CAS has four subtests that measure these processes and the names of the subtests are the same as the four categories of the PASS model: Attention, Planning, Simultaneous and Successive Processing. The CAS allows for the practice of only utilising certain of the subtests in order to measure those specific processes (Das, et al., 1993, p. 7). For the purposes of this study the subtests of Planning and Simultaneous Processing were selected as they were considered to measure the abilities most related to engineering. The Planning subtests required the student to create a plan of action, apply the plan, verify that an action taken conformed with the original goal, and modify the plan as needed. The Simultaneous subtests required the synthesis of separate elements into an interrelated group using both verbal and non-verbal content (Das, et al., 1993, p 21). The reliability coefficients are consistent with what is typical for a test of cognitive abilities, and average reliabilities for the Planning subtest and Simultaneous subtests are 0.88 and 0.93, respectively (Das, et al., 1993, p. 44). Studies conducted in South Africa by Reid (2001) and Phellows (2004) show similar reliability coefficients in their research.

The CAS (Appendix I) is a measurement tool that demonstrates how cognitive processes can change, evolve and develop and is a suitable method of assessing whether a mediated learning experience has altered intellectual functioning. Therefore, it would seem to be an apt measurement to use in a pre- and post-test methodology as it can measure whether there is improvement in cognitive processing and hence intellectual functioning of the student, subsequent to the mediation of the cognitive functions intervention programme.

3.7. Ethical Considerations

In conjunction with the School of Process and Metallurgical Engineering (PRME), the researcher made every effort to consider the ethical implications for the students of participation in this study. At the beginning of the academic year, the researcher was introduced to the first-year Metallurgy students. At that meeting Mr. Woollacott, the co-ordinator of first-year PRME, outlined the academic enrichment programme planned as part of the Friday tutorial lesson. He informed them as to the nature and reason for the programme, as well as that participation was entirely voluntary, but recommended, given the benefit past students had derived from the programme. The researcher had an opportunity to tell the students about her study and inform them that subject information sheets and consent forms would be handed out the following week (Appendix C). Again, the voluntary nature of participating in the study was emphasised.

The following week, the students were given written information about the programme. The subject information letter apprised the students of the time frame of the cognitive mediation programme, that is, 12 weeks from July to September. The sheet assured the students that all data would be anonymous and confidential. Permission to utilise the data for future research was sought from the students, and an undertaking given that feedback from the study would be issued at the beginning of the 2006 academic year.

A consent form was included at the end of the subject information sheet. Students were asked to sign it and return it if they agreed to participate in the mediation programme. All 20 students signed the consent form and participated in the mediation programme.

3.8. Procedure

3.8.1. Pre-tests

The School of Process and Metallurgical Engineering, in conjunction with the then Discipline of Specialised Education, administered the CAS (Das & Naglieri, 1993) at the beginning of the academic year (Appendix I). This was done in order to establish a baseline against which the student's future academic performance could be gauged. The mid-year examinations results were recorded as a baseline for academic achievement.

The researcher and four Educational Psychology Masters Students conducted the baseline measurements on Friday afternoons over a four-week period. The 20 Metallurgy students were randomly divided into sets of five. Each Friday afternoon, the five master's students, concurrently administered the subtests on a one-on-one basis to the five first-year Metallurgy students. This occurred in separate venues. Each student completed the Planning and Simultaneous scales of the Cognitive Assessment System (Das, et al., 1993) .The test administration took approximately one hour. The first-year students then returned to class for their afternoon tutorial with the course co-ordinator and tutors. The researcher scored the tests and all the data was checked by a member of the School of PRME.

3.8.2. Intervention

At the beginning of the academic year, the first-year Metallurgy students were given information about the ongoing project involving The School of PRME. They were informed about the pre- and post-tests as well as the cognitive mediation programme scheduled for the 3rd and 4th quarter of the academic year during the

regular tutorial time on Fridays. All 20 students signed forms consenting to be part of the project, acknowledging that should they not wish to participate, they were not obliged to and could withdraw at any time without prejudice (Appendix C).

The cognitive intervention programme consisted of 12 sessions, one session per week from July until September. Each session focused on one aspect of Feuerstein's Instrumental Enrichment programme adapted by Professor Skuy (2003), which was prepared so that it related metacognitively to the PRME tutorial for that week. (Appendix D). The cognitive mediated intervention took approximately forty minutes of the scheduled hour. In the remaining twenty minutes of the class, the Junior Lecturer posed an engineering problem to the students that was appropriate to the psychological tool taught in the intervention programme. After ten minutes of allowing the students to come up with the solution, the Junior Lecturer then used this as a vehicle to mediate the cognitive function learned earlier and transfer the learning into an engineering medium. The students were able to ask questions and have the Junior Lecturer facilitate any difficulties they had in understanding the engineering exercise (Appendix E). After the lunch break the Metallurgy students returned to class for their weekly Friday afternoon tutorial with tutors and the course co-ordinator, Mr. Woollacott. Each week for the duration of the intervention, Mr. Woollacott and the researcher met and discussed the cognitive function planned for mediation that Friday. As the course co-ordinator, he endeavoured to re-inforce, utilise and teach the mediated cognitive function of the day in the PRME (1002) afternoon tutorial.

3.8.3. Post-tests

The administration of the CAS (Das & Naglieri, 1993), post-tests took place a few weeks after completion of the intervention programme and a week before the final end-of-year examinations.

The researcher and four Educational Psychology Masters Students conducted the assessments on a Friday afternoon over a two-week period. The 20 Metallurgy students were randomly divided into sets of five. Each Friday afternoon, the five

Masters students, concurrently administered the subtests on a one-on-one basis to five first-year Metallurgy students. After each student was finished they returned to class for their afternoon tutorial with the course co-ordinator and tutors. The next five students then left the afternoon tutorial class and were tested concurrently for an hour in separate venues by the researcher and four Masters Students. When these five students were finished they returned to class for their afternoon tutorial with the course co-ordinator and tutors. Each student completed the Planning and Simultaneous scales of the Cognitive Assessment System (Das, et al., 1993). The researcher scored the tests and all the data was checked by a member of the School of PRME.

CHAPTER FOUR
RESULTS

4.1. Overview of Data Analysis

Descriptive and inferential statistics were employed to analyse the data from the responses of the participants of the study. The Statistical analysis system, Statgraphics (www.statgraphics.com), was utilised to conduct the statistical analyses (Appendix E). The study utilised the raw and not scaled scores for all the data. The reason was to control for any confounding variables due to the fact that The Cognitive Assessment System (CAS) is not standardised for individuals older than 17 years of age. It was necessary to determine the distribution of the pre- and post-test scores for the 6 subtests of the Planning and Simultaneous scales of the CAS test, as well as for the mid-year and end-of-year examination scores. The Kolmogorov-Smirov test of Goodness-of-Fit was used for this purpose. The results demonstrated a normal distribution for all the subtests and examination scores.

Table 4.1 shows the results of the Goodness-of-Fit test for the end-of-year examination scores.

Goodness-of-Fit Tests for End-of-year Examinations

Table 4.1. Kolmogorov-Smirnov Test

	Normal
DPLUS	0.118115
DMINUS	0.100527
DN	0.118115
P-Value	0.942979

The StatAdvisor

This pane shows the results of tests run to determine whether End-of-year Exams can be adequately modelled by a normal distribution. Since the smallest P-value amongst the tests performed is greater than or equal to 0.05, we can not reject the idea that End-of-Year Exams comes from a normal distribution with 95% confidence.

Figure 4.1 graphically depicts the Histogram of the end-of-year examination scores which demonstrates the normal distribution curve.

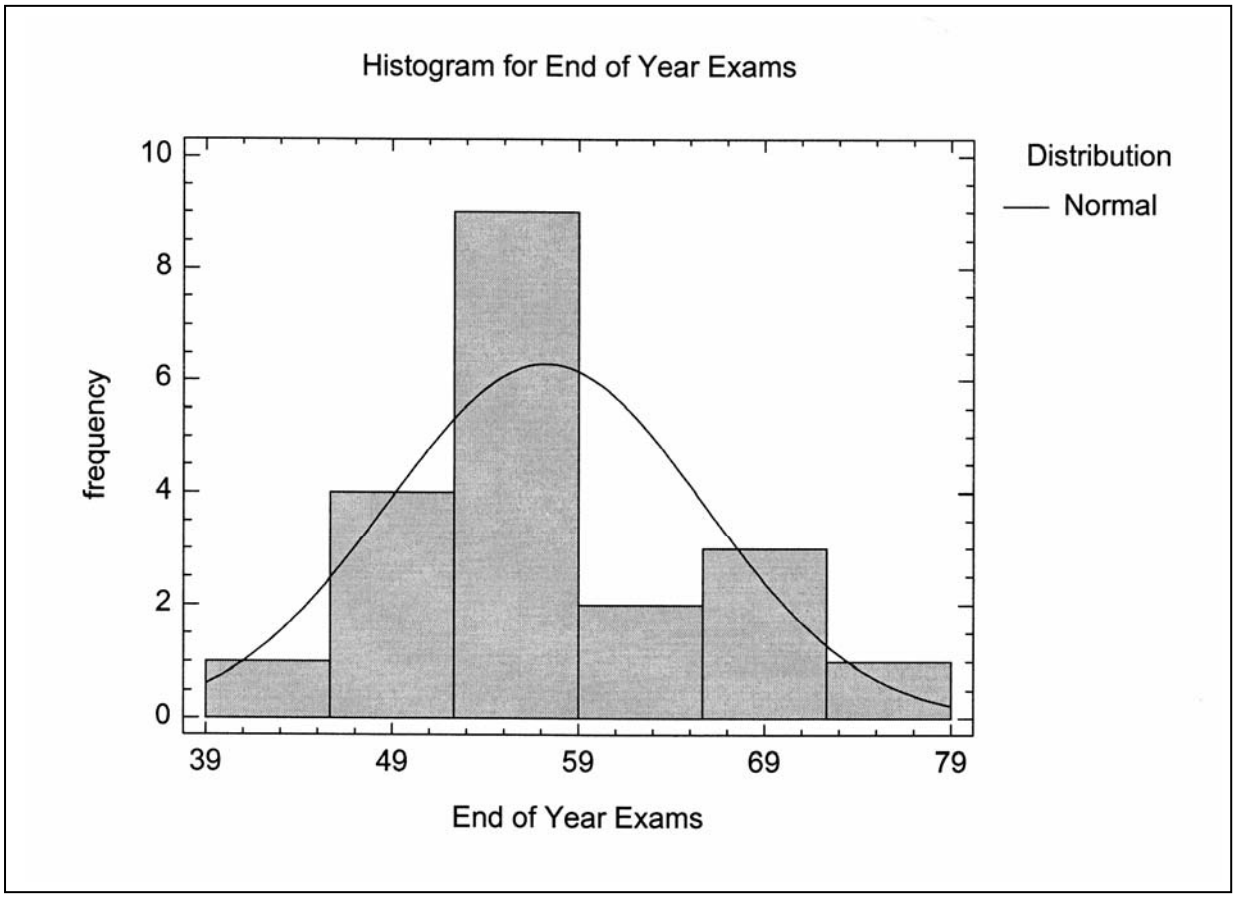

Figure 4.1. Histogram of the End-of-year examination.

Figure 4.2 shows the scatterplot graph depicting the normal distribution of the end-of-year examination scores.

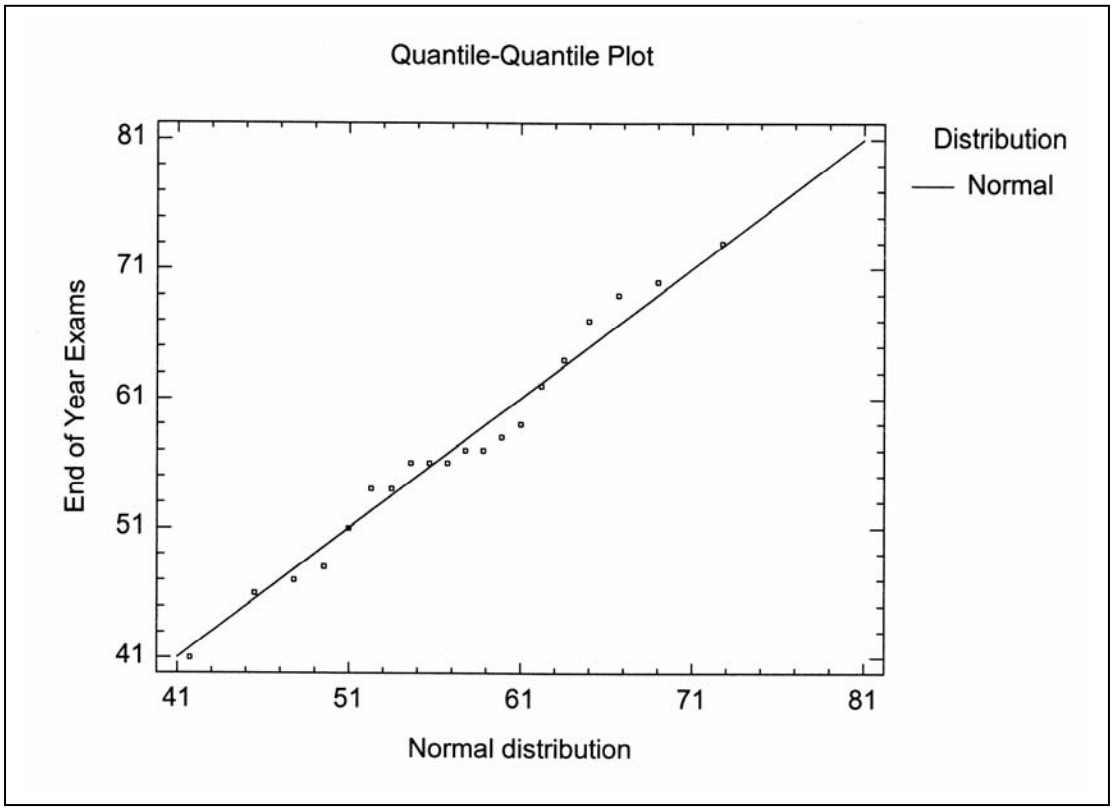

Figure 4.2. Scatterplot Graph

On account of the assumption of normality being met and because all the dependent variables (scores of post-test subtests and end-of-year examination) were measured on an interval measurement scale, the researcher used parametric statistical procedures. The study utilised the Matched Paired t-Test procedure in order to find out if there was a significant difference between pre- and post-test results.

4.2. Descriptive Statistics

The first level of analysis describes the sample, in terms of mean scores percentages and range of the participants. The demographic information about the sample is presented in Table 4.2. The sample consisted of 75% males and 25% females. The ages ranged from 17 to 26 years, with a mean age of 19.2.

Table 4.2. *Demographic Information of the Sample*

RACE			GENDER			AGE		
	n	**%**		**n**	**%**	**Mean**	**n**	**Range**
Black	16	80	Male	15	75	19.2	20	17-26
White	1	5	Female	5	25			
Asian	3	15						

The pre- and post-test means and standard deviations of the six CAS subtests and examination results are presented in Table 4.3 and Table 4.4. In examining the difference in mean scores between each of the pre- and post-subtests, it is evident that the only subtests exhibiting obviously large improvements, in terms of the first and second administration of the subtests, is that of Planned Codes and Planned Connections. Planned Connections is a timed subtest that is scored according to how long the student took to complete the test. The importance of this is that the less time the student needed, the better their score. Thus, the fact that the mean score was less by 31 points in the November administration and the Planned Codes mean test score was 31 points higher indicates a similar improvement. The remaining four subtests results showed that the means between the pre-and post-test scores demonstrated an improvement, which can only be determined as significant through statistical measurement procedures. The examination results showed that the means between the pre-and post-test scores demonstrated a very slight improvement of less than one percent.

Table 4.3. Mean scores on the examination results

June Examination 2005 (Mid Year)					November Examination 2005 (End Year)				
n	**Mean %**	**SD**	**Min %**	**Max %**	**n**	**Mean %**	**SD**	**Min %**	**Max %**
20	56.8	8.7	47	72	20	57.3	8.5	41	73

Table 4.4. Mean scores on the six subtests of the CAS

CAS SUBTESTS	PRE-TEST MARCH					POST TEST NOVEMBER				
	n	**Mean**	**SD**	**Min value**	**Max value**	**n**	**Mean**	**SD**	**Min value**	**Max value**
Planning Scale										
Matching Numbers	20	12.5	2.4	8	17	20	14.3	3.4	10	25
Planned Codes	20	75.9	39.2	42	122	20	106.4	29.2	67	172
Planned Connections	20	143.1	22.4	67	210	20	112.5	34.6	70	186
	n	**Mean**	**SD**	**Min value**	**Max value**	**n**	**Mean**	**SD**	**Min value**	**Max value**
Simultaneous Scale										
Non Verbal Matrices	20	25.3	6.7	2	32	20	28.4	2.7	19	30
Verbal Spatial Relations	20	22.2	3.2	15	27	20	24.3	1.9	20	27
Figure Memory	20	21.9	3.2	14	26	20	24.1	2.5	17	26

4.3. Inferential Statistics

In this study two research questions were asked. The first research question posed was: following the intervention, would the academic performance of the Metallurgy students improve as measured by the difference between mid-year and end-of-year examination results? To determine whether a significant improvement resulted, Matched Paired t-Tests were conducted for the whole sample on the pre- and post-test scores of the examination results. As demonstrated by Table 4.5, the t-Tests revealed no statistically significant differences between the pre- and post-test scores of the examination results. Since the p-value was 0.6, which is greater than 0.05, we cannot reject the null hypothesis for alpha 0.05. This means that the statistical procedures indicate that the means of both administrations of the examinations are equal and thus show no significant difference. In this regard the results failed to answer the research question in the affirmative. Thus, it can be inferred from the statistics that an extended cognitive mediated intervention programme did not significantly improve first-year Metallurgical students' academic performance.

Table 4.5. Results of match paired t-Tests for each CAS subtest and mid-year and end-year examinations

Subtests and Examinations	**t-Test Statistic Value**	**P-Value**
Matching Numbers	3.801	0.002*
Planned Codes	3.373	0.001*
Planned Connections	-4.006	0.00*
Non-verbal Matrices	2.0373	0.055*
Verbal Spatial Relations	2.4095	0.026*
Figure Memory	3.7256	0.001*
Examinations	0.5325	0.600 **NS**

* $p < 0.05$ **NS** = Not Significant

The second research question posited if the intervention programme would result in a significant difference in intellectual functioning of the students as measured by the pre- and post-test results of the Cognitive Assessment System (CAS).

Table 4.5 demonstrates that there was a significant difference in all of the six subtests. The Planning scale of the CAS showed a significant difference in all three subtests. The Simultaneous Scale also had p-values that indicated significant differences in all three subtests. Since the p-values of all the CAS subtests were less than 0.05, we can reject the null hypothesis for alpha 0.05. This means that the statistical procedures indicate that the means of both administrations of the CAS subtests are not equal and thus show significant differences. Thus, it can be inferred that the mediated cognitive intervention programme did have a positive effect on, and improved the cognitive skills of planning and simultaneous functioning, as defined by Das and Naglieri (1993).

The researcher conducted Pearson's Product Moment (r) correlation tests to test if there was a relationship between the improvement in intellectual functioning, as shown by the post-test scores of the CAS, and academic performance, as measured by the end-of- year examination results. The results shown in Table 4.6 reveal that there was no correlation between these two variables.

The Pearson's Correlation coefficient statistic was close to r = 0 for most of the relationships between the subtests and the examination results which indicates no linear relationship between the variables. The only relationship that displayed a moderate correlation was that between the subtest of Planned Connections and the November, end-of-year examination results. The coefficient statistic was r = 0.320 which is still on the lower end of the moderate scale and therefore cannot be regarded as significant. This implies that although the intervention may have had an impact on the intellectual functioning of the students, this did not transfer into a notable difference in academic performance as measured by the November examination results.

Table 4.6. Correlations between the CAS post subtests with the end-of-year examinations (Pearson's Product Moment Correlation Coefficient = r)

CAS Post Subtests	November Examinations Results
Matching Numbers	0.068
Planned Codes	0.144
Planned Connections	0.320
Non-verbal Matrices	0.180
Verbal Spatial Relations	-0.008
Figure Memory	0.151

r between 0.1 and 0.3 = negligible correlation

r between 0.3 and 0.5 = moderate correlation

4.4. Conclusion

The results demonstrate that there was a significant improvement in intellectual functioning of the first-year Metallurgy students following the intervention. This was shown by the statistical analysis of Matched Paired t-Tests conducted on the differences between the pre- and post-test scores of the CAS. There was no significant difference in the academic performance of the students as shown by the less than 1% improvement between the means of the mid-year and end-of-year examination results. Thus, although the cognitive mediated intervention had a significant positive effect on intellectual functioning of the students, the cognitive mediated intervention programme did not have an effect on improving academic performance, which was the ultimate intention of the intervention programme.

CHAPTER FIVE
DISCUSSION

The current study investigated the effects of an extended cognitive mediation programme on the academic performance and intellectual functioning of 20 first-year Metallurgical engineering students. This section discusses and interprets the research findings, presented in Chapter Four, in the light of empirical studies and current theories of mediation, intellectual functioning and transfer, as explored in literature review. The possible reasons for and the implications of the findings are also discussed.

The first research question that was posed, focused on the effects of the extended mediated cognitive intervention programme on the academic performance of the 20 Metallurgy students as measured by the examination results. The second research question focused on whether an extended cognitive mediation programme would improve the intellectual functioning of the 20 Metallurgy students as measured by the pre- and post-test scores of the CAS.

5.1. Improvement in academic performance

It was anticipated that by extending the cognitive mediation intervention programme from 5 weeks to 12 weeks, the 20 Metallurgical engineering students would demonstrate a significant improvement in their end-of-year examination results as compared with their mid-year examination results. The results suggested that no statistically significant improvement was effected. These findings corroborate the results recorded by the study with Viviers' research (2004) that academically weaker students showed no significant improvement in their academic performance post intervention. The current research sample of first-year Metallurgy students was not considered borderline, that is, failing, but with the potential to pass, as in the sample used in Viviers study (2004). However, the Metallurgy students were considered academically weaker, by an average of 10%, with historically higher attrition rates, than their first-year Chemical engineering

counterparts, as measured by the point allocation system for entry to university (Woollacott, personal communication, 2005). These results also indicate that increasing the duration of the cognitive mediated intervention programme, from 5 weeks to 12 weeks, has not made a significant difference in enhancing academic achievement.

As the reasons for the results of this research have important implications for the present School of Chemical and Metallurgical Engineering and their design of the course for first-year students, the researcher will in a systematic manner, endeavour to explain her critical analysis of the results of the research and the possible reasons therefore.

5.2. Critical Analysis of reasons for the results in 5.1

5.2.1. Underpreparedness of the first–year students

In Chapter One the issue of underpreparedness was raised. The Metallurgy students may be underprepared for the level of conceptual difficulty, as well as for the high workload of the PRME (1002) course. Out of the 20 students in the sample, 15 students attended secondary schools that would have been considered to fall under the previous Department of Education and Training (PRME, intake information, 2005). As explained in the historical background in Chapter One, many of these schools were not adequately equipped with teachers, classrooms or teaching materials. Although the students matriculated in 2003/4, studies suggest that in the approximately ten years since democracy, many of these previously disadvantaged schools continued to have problems of under-skilled teachers, overcrowded classrooms and a rote, algorithmic rule-based learning environment (Case, et al., 2003; Foxcroft & Roodt, 2001; Mangangane, 2003 & Strous, 2003).

Consequently, a large proportion of the sample studied, it could be argued, entered first-year university at a disadvantage in terms of quality secondary education provision. Although the matriculation point average ranged from the mid- to high-30 range, indicating excellent matriculation results, most probably their learning

and understanding of high school academic material had been based on the linear, surface, algorithmic learning style explained in the literature review (Case, et al., 2003).

Therefore, the sample of first-year Metallurgy students in the current study, arrived with a repertoire of learning behaviours that were not conducive to the demands of tertiary education, and for the conceptual difficulty of the PRME (1002) course, in particular. It may be assumed that this impacted negatively on the students' learning experience, which in turn may account for no significant difference being attained in academic achievement, as measured by the examination results.

5.2.2. Underpreparedness of the curriculum

One of the aims of the pilot study (2001-2003) was to implement curriculum changes within the PRME (1002) course that would take into account the underpreparedness of the student. The thinking was to narrow the gap between the competencies of the incoming students and their surface learning approaches, and the requirements of the course, to inculcate complex, conceptual knowledge and understanding of the engineering material. This was implemented in the form of the collaborative learning environment, increased group work and tutor involvement, as well by changing the assessment procedures, as explained in the history of the programme in Chapter Three.

In 2003, Henning conducted a study aimed at assessing how effective these changes had been and at recommending what further improvements could be made. Henning did this by researching the various perceptions that students had of the PRME (1002) course and the relationship between these perceptions and their approaches to learning. Her research examined the obstacles that students perceived to be causing them difficulties in the course. Consequently certain changes were recommended. Henning's study, released in 2005, revealed a number of interesting results. The findings demonstrated that many of the students had entered the course with *surface* approaches to learning, the same learning style that had been effective in achieving their good matriculation results. The students realised that they needed

to change to a *deep* learning approach in order to understand and conceptually assimilate the engineering coursework. However, the study shows that for many of the students there were elements of the course that discouraged them from adopting a *deep* approach to learning. Some of these perceived obstacles were:

- The perception that the course outline in the course manual was incomplete and lacking in detail, thus hindering students' ability to prepare in advance for lectures.

- The perception that tests contained "twists" that the students were unable to prepare for or predict.

- The perception of a lack of constructive and helpful feedback from tutors and the course co-ordinator on returned tests and assignments (Henning, 2005, p. 95).

Another important finding in the Henning study was the students' perception that what was learnt in the course was irrelevant to their careers of being engineers (Henning, 2005, pp. 94-96).

Although Henning's research was only printed in 2005, the faculty of PRME and the course co-ordinator had access to the findings by 2004.

5.2.3. Curriculum changes

The School of PRME evaluated these research findings and once again reorganized the course. The course co-ordinator took into account the obstacles perceived by the PRME (1002) students' which prevented their really coming to grips with the course material. The course manual was rewritten to include detailed outlines and explanations of the work programme to be covered in the year. The course co-ordinator and tutors made a concerted effort to give detailed and constructive feedback on tests and assignments. In the Friday afternoon tutorial, time was made available for students who were confused about any work covered that week. There

were opportunities provided for their questions to be answered individually, or as a group, by an experienced tutor or the course co-ordinator (Woollacott, personal communication, 2005).

With renewed determination the school of PRME decided to continue to do research on this course in 2005. This was in line with many other universities both in South Africa and overseas, who were evaluating and redesigning their science and engineering courses (Case, et al, 2003; De Haan, 2005; & Davis & Wilcock, 2004). A review of some of the literature suggested that science and engineering courses needed to move away from traditional lecture based formats, to active learning and participatory environments. This was based on substantial evidence (Glenn Commission Report, 2000) which showed that science undergraduates, who became actively engaged in their own learning, could produce levels of understanding, retention and transfer of knowledge that was far greater than that obtained by students taught in traditional lecture/laboratory classes (De Haan, 2005).

The School of PRME had, since 2001, instituted these changes in terms of active and collaborative learning. The changes had **not** dramatically altered students' academic achievement or their conceptual understanding of the course. Thus, the thinking was to examine different methods of active learning used successfully by other universities in their engineering courses, and to look at incorporating such methods into PRME (1002). A method that had been tried by three different universities in engineering courses and that was corroborated by published research to have been successful, was the case-based approach. Raju (1999), Felder (1995), and Davis and Wilcock (2004) reported that using this approach increased the engineering students' problem solving abilities. Only Felder (1995) could show that this active and cooperative learning method improved students' academic achievement. The course co-ordinator adopted Davis and Wilcock's (2004) definition of the case study as a student-centred activity, based on a topic that demonstrates theoretical concepts in an applied setting (Kotta, 2006, p. 9). Thus, the case-based approach, which uses case studies that depict real events that students can analyse, was factored into the curriculum.

Kotta comments that the use of the case-based approach was to enable students to become informed participants in a discourse with the aim to promote epistemological access (2006, p. 9). The reason for this was that in the course co-ordinator's evaluation of all the changes made to the course since 2001, the conclusion reached was that the students' problem solving abilities and grasp of the multifaceted and conceptual nature of the process engineering course were still compromised. Mr. Woollacott explained the reasons for this as "the students' inability to tap into a wider range of resources in terms of other coursework; and inability to use the available resources adequately; an inability to read problem situations accurately before embarking upon a solution strategy; and solution strategies that lacked the robustness to illustrate a deep level of engagement. In other words Mr. Woollacott attempted to address the fact that the students had failed to see the relevance of the work in light of their desires to be engineers." (Kotta, 2006, p. 9).

Kotta (2006) conducted research to evaluate the effectiveness of using the case-based approach in PRME (1002). This change in the curriculum of PRME (1002) in 2005 coincided with the year of this researcher's study with the same sample of students.

Kotta's research on the efficacy of the case-based approach revealed interesting results (2006). The study explained how the case-based approach is founded on the theoretical frameworks of context and active learning. The literature reviewed showed that studies conducted on this revealed that context-rich and active learning environments improved students' thinking and problem solving skills. Hence, the course co-ordinator made the logical assumption that adopting this approach with the PRME (1002) students' could possibly improve their thinking and problem solving skills. However, this was unfortunately not substantiated in the research (Kotta, 2006). Kotta's findings reveal comprehensive and complex reasons for the failure of the case-based approach. The most salient and relevant reasons for the current research centre around two main learning theories involved in the active construction of knowledge. The first is the learning theory of Piaget (1968). As explained in the literature review, the concept of disequilibration requires the student to either accommodate or assimilate the information in order to resolve the

cognitive conflict and to actively construct new knowledge. From the study, it appears that the majority of students were unable to do this. They simply ignored the conflict and made up their own answers by returning to linear, algorithmic thought processes which they had learned at school and with which they felt comfortable.

Kotta's study concluded “that in order for the case-based approach to succeed, the students needed to be able to reconstruct or restructure their knowledge when faced with an unfamiliar problem. In this way they would gain access to new knowledge or a new way of thinking. However, most of the students when faced with an unfamiliar problem, recognized the contradiction, but ignored it and invented evidence and representations that did not reconstruct or restructure.” (2006, p. 146).

The second reason relevant to the present study, as to why the case-based approach appeared to fail, is that the concept of scaffolding and mediated learning (Bruner, 1977; Vygotsky, 1978 a, b) was not evidenced as forming an important part of the learning environment. The case-based approach method embeds the content and the process of the engineering problem in a context. This context-rich problem makes the assumption that the way in which the problem is framed, will send signals to the students of the nature of the problem and of the appropriate strategies needed to solve the problem. However, if a context is too complicated and overwhelming for the student, the student is completely lost, as he or she lacks the logical structures necessary to try and work out the problem and has no more experienced learner to assist or guide him/her. Kotta comments “this is tantamount to taking a student who does not yet possess a certain skill, and putting them in a situation that requires that they use the skill they do not yet have” (2006, p. 148).

Thus, it would appear that the gap between the competencies of the incoming students and the conceptual complex competencies required of them in the engineering course, is too large to be bridged in the first-year PRME (1002) course. Even though the School of PRME has consistently, and with great persistence, attempted to continually modify and adapt the PRME (1002) curriculum and learning environment, in order to optimally facilitate the divide between what students bring into the course and what the engineering course requires, the gap

continues to be a major problem. This is further exacerbated by the fact that the other core courses in first-year Metallurgy: Mathematics, Physics and Chemistry follow the secondary education algorithmic learning and assessment structures (Kotta, 2006). Thus, PRME (1002) is the only first-year course in the School of PRME that is completely different in content, structure, learning environment, assessment and outcome requirements.

This gap between school provision and university requirements is a problem that universities overseas are also experiencing. A pilot survey of science students at the University of Ulster concluded that students are not bridging the gap between school and university quickly and effectively and this is in turn placing the students "at risk, if not from dropout, then from underperformance" (Lowe & Cook, 2003, p. 53).

Consequently it may be inferred that the chasm between the competencies of the incoming students and the necessary conceptual competencies required by the PRME (1002) course remains very wide, despite attempts to reduce it through changes in the curriculum. This may have negatively impacted on the students' results and academic performance, with particular reference to the examination results.

5.2.4. The problem of transfer

As mentioned in the literature review, the issue of whether knowledge can be successfully transferred from one context to another remains problematic (Hennessy, McCormack & Murphy 1993; Perkins & Salamon, 1988, 1989). The intervention of this research aimed at targeting the higher-level executive processes, that is *high road* transfer, as defined by Perkins, et al., (1992, 2005). The attempt to apply mindful extraction of cognitive functions and deliberately search for connections in the engineering context was implemented in a number of ways:

- The intervention utilised the concept of meta-cognition (students thinking about their thinking). Each Friday, when a new cognitive function was

mediated, the students debated with each other and the researcher as to exactly how this was going to help them in the PRME (1002) course-engineering context. As early as 1980, literature supported the idea that meta- knowledge or cognition was central to the issue of transfer (Belmont, Butterfield & Ferretti, 1980). Since then studies, both in South Africa and abroad, have substantiated this claim (De Haan, 2005; Gamache, 2002; Mehl, 1991; Osman & Hannafin (1992); Sibaya, Hlongwane & Makunga, 1996).

- The intervention taught cognitive functions based on the adapted Instrumental Enrichment (IE) programme by Professor Skuy. These cognitive functions were specifically thought to be relevant to the engineering context. For example, the cognitive function of categorization was explained to the students to help them to identify information that should be grouped together. The students found this relevant and useful. Thus, the students made connections between the cognitive function and the engineering context (Perkins, et al.,1992, 2005) as demonstrated by the evaluation of the intervention programme (some examples are included in Appendix G).

- The Junior Lecturer directly mediated the cognitive function practised/taught, for example categorization, in an engineering exercise problem. Thus, the students were able to see the relevance of what they had learned in the engineering context. In this particular case, the concept of molecular concentration can be better understood when grouped into categories. (The engineering exercise of categorization is included in Appendix D)

The evaluations written by the students, on completion of the intervention programme, suggested that they had found the programme extremely useful in two main ways. Firstly it had helped them to clarify and sort out information into chunks that they could understand and assimilate. Secondly, they were then able to use their newly acquired skill in dealing with the engineering problem which had

initially appeared overwhelming, because of the overload of information (See Appendix G).

Despite the attempts to teach for *high road* transfer, the skills learnt in the intervention were not sufficient to make a significant difference in the Metallurgy students' academic performance as measured by the examination results. This corroborates the findings of Bereiter & Scardmalia (1989), Detterman & Sternberg (1993) and Salomon & Perkins (1988) that transfer of knowledge is not automatic and does sometimes fail. This points to the fact that transfer is a very complicated concept, which still needs further research, as the implications for education and engineering in particular, are enormous.

5.3. Improvement in intellectual functioning

The study anticipated that the extended cognitive mediation programme would improve the intellectual functioning of the 20 Metallurgy students as shown by the differences in the pre- and post-test scores on the Cognitive Assessment System.

The results demonstrate that there was a significant improvement for each of the subtests in the Planning and Simultaneous scales of the CAS following the cognitive mediation programme. This underscores Feuerstein's belief and research and endorses the cognitive modifiability of the human brain. The results also revealed that, in line with the different evaluative meta-analyses of IE, as mentioned in the literature review (Blagg, 1991; Bradley, 1993; and Romsey & Samuels, 2001), that cognitive mediation does have a positive effect on intellectual functioning.

5.3.1. Critical analysis of reasons for the results listed above.

5.3.1.1. The Effect of Maturation

The first-year Metallurgy students began and finished the course over a period of approximately 11 months. Their high entrance points (33 and above for all of the students in the sample) indicate that they are intelligent according to the matriculation results, which are considered by numerous authorities (psychometrists, universities, corporates, etc.) to be a good indicator or predictor of general intelligence (Gottfredson,1998; Kuncel, Hezlet & Ones, 2004; Schmidt & Hunter, 2004). Studies conducted both locally and internationally indicate that engineering students are among the highest scoring candidates on intelligence tests (Jones & Bell, 1980; Rushton, Skuy & Fridjhon, 2003; Skuy, Gewer, Osrin, Khunou, Fridjhon & Rushton, 2002). Over a period of 11 months, it is logical to assume that students mature both chronologically and intellectually, when actively engaged in stimulating intellectual exercises (McBurney, 2001). Thus, the significant differences between the pre-and post-scores of the CAS could be due to the effect of the intellectual maturation of the Metallurgy students.

5.3.1.2. The cognitive mediated intervention programme

The intervention programme was designed using Professor Skuy's (2003) adapted version of Feuerstein’s Instrumental Enrichment programme. As explicated in the methodology section, the Cognitive Assessment System (CAS) was designed by Das and Naglieri (1993), who were influenced by the work of the neuropsychologist, Luria (1966). Luria, like Feuerstein viewed the brain as an autoplastic system, able to change and adapt to the environment. Thus the CAS is a measurement tool that demonstrates how cognitive processes can change, evolve and develop by measuring the cognitive processing of the individual. The cognitive mediated intervention programme was based on the theoretical framework of Feuerstein’s cognitive functions, which relates well to the theoretical framework of Das and Naglieri’s cognitive processing PASS model. Thus, the significant differences between the pre- and post-test scores of the CAS may have been

positively affected, or influenced by, the mediation of the cognitive functions used in the intervention programme.

5.4. Possible reasons for results discrepancies

Although there was a significant difference in intellectual functioning as measured by the pre- and post-test scores of the CAS, this did not have a significant influence on the academic achievement of the Metallurgy students, as measured by the examination results.

5.4.1. Research findings that critique cognitive mediation

The final section of the literature review examines critiques by various researchers on the findings of cognitive mediation studies. A theme that was repeated was the fact that although the studies could show improvement in intellectual functioning post the intervention, this was often not validated in certain achievement measures. Hence, the issue of cognitive mediation facilitating transfer from improvement in intellectual functioning to tangible results in improvement in academic achievement was questioned (Blagg, 1991; Bradley, 1993; Shayer & Beasly, 1987; Romney & Samuels, 2001). The current study appears to support these critiques. The researcher findings showed similar results to the South African studies of Gaydon (1988) and Shochet (1994). The cognitive mediated intervention programme resulted in improved intellectual functioning of the students as measured by the pre- and post-test scores of the CAS, but this did not transfer into improved academic achievement as measured by the examination results.

5.5. Summary of the research findings

The implementation of an extended cognitive mediated intervention programme made no significant difference to the academic performance of the first-year Metallurgy students as measured by the examination results. However, it did significantly improve the intellectual functioning of the first-year Metallurgy students between the beginning and the end of the academic year as shown by the differences in scores between the pre- and post-test scores of CAS. Thus the research corroborated the findings of the critical evaluation of the previously mentioned IE programmes. Although statistically significant improvement occurred in the intellectual functioning of the students, this did not translate into measurable gains on the chosen achievement measure, the end-of-year examination. Thus again, in line with previous studies mentioned in the literature review, the problem of transfer was highlighted in the current research. Of extreme relevance is the fact that the cognitive mediation intervention programme was designed to include direct transfer of cognitive functions into an engineering medium, through the utilization of engineering problems, facilitated by a Junior lecturer in the School of PRME. This still had no measurable effect on the academic performance of the students, as seen in the examination results.

CHAPTER SIX
RECOMMENDATIONS AND CONCLUSION

In the previous chapter a critical evaluation of possible reasons contributing to the results of the research was explored. One of the main factors found to be a cause for concern is the gap between the incoming competencies and learning styles of the students, and the academic conceptual competencies and deeper learning approach required for successful academic achievement to occur in the PRME (1002) course. This study demonstrated that mediation of cognitive functions did not help to close this gap; the problem remains. An evaluation needs to be made of the options available.

Many other universities in South Africa have found this to be a problem, not only in engineering courses, but also in courses in which the students study to become chartered accountants. The Faculties of Economic and Financial Sciences have found that bridging courses, or supplementary measures, have failed to make a notable difference to the attrition rates and throughput numbers of graduating students (J. Griffioen, personal communication, February 5, 2007). The University of Johannesburg, in consultation with SAICA (the South African Institute of Chartered Accountants) decided at the end of 2004, that a radical new plan needed to be developed to help previously disadvantaged students to complete the undergraduate course. These B.Comm. Accounting students needed to achieve sufficient understanding and competency in order to graduate and complete their articles and be able to write the board examinations for chartered accountants. One of the main motivations was that, according to the SAICA data-base, only 750 out of the 24,000 currently registered chartered accountants in South Africa, are black. A bold initiative was introduced to reduce the imbalance in accordance with government's and the corporate sector's commitment to employment equity in South Africa.

SAICA created a bursary fund called the Thuthuka Fund which pledged to make available R 25,000 for 50 first-year students per annum amounting to R1.25 million

per annum. The University of Johannesburg then approached the National Student Fund for Aid (NISFAS) to pledge a further R 25,000 per student resulting in 50 bursaries of R50, 000 at a value of R2.5 million being raised. Mr. Jelvin Griffioen was appointed project manager and was responsible for liaising with all the stakeholders: SAICA, NISFAS, the University of Johannesburg and the students. His first job was to hire a private hostel in Brixton, close to the University of Johannesburg for the selected students. Their accommodation and food was covered through the bursary fund. The Brixton Hostel was structurally re-fitted to provide study areas for the students, as well as the tutors and the project manager. The selection process followed this phase. This was a very important part of the process, as all the stakeholders wanted to ensure that the students selected would have the potential and the persistence to participate in and complete the project and ultimately fulfil their roles as registered chartered accountants in South Africa. Previously disadvantaged applicants from all over South Africa were invited to apply. In terms of academic qualifications, the applicants needed to have obtained an A, B or C symbol in Mathematics (Higher Grade) in their July examinations. Other marks were considered but no other stringent criteria were applied. A selection of approximately 250, students that fulfilled the initial criteria, was made from the many thousands of applicants.

SAICA selected a panel to travel the country interviewing the prospective applicants. Criteria such as disposition, resilience and the desire to succeed were assessed as well as the panel's perception of the students' academic, interpersonal and teamwork abilities. In this way the 50 first-year B.Comm. Accounting bursary students were selected to study at The University of Johannesburg. The official starting date of the project was 1 January 2005. The selected students travelled to Johannesburg to reside at the Brixton Hostel. This included the local Gauteng students, as part of the project's aim was to provide optimal living and studying environment for the students as well as access to computers.

The project identified that the subjects of accounting and statistics, of all the first-year courses, had historically caused the most difficulty for the students. Accordingly, an extra class per week in these subjects was provided for the students. Each week these students wrote an extra test for the duration of

approximately an hour. Directly after the test, the tutors (third-year students who were paid from the Thuthuka Fund) assisted the first-year students to work through the test, identify problem areas and provide explanations. The tests were collected by the tutors, marked rigorously and returned to the students the following week with individual feedback. Particular emphasis was placed on the understanding of the material, as well as examination techniques. This routine was followed consistently for the whole year. The project manager and the tutors also lived in the hostel with the students and were available to help in the evenings during the set study time of 7-11 p.m.

At the end of 2005, the results of the programme were phenomenal. The first-year throughput (pass) rate was 90%. This entailed obtaining 60% for accounting and passing all the other subjects required in order to become a chartered accountant. In 2006, these students entered second-year and would continue to be bursary recipients if they passed. Some of the second-year students had opportunities to become tutors to the 2006 first-year intake and for this they received a stipend of R500 per month. The same formula of providing extra lessons in each subject and the marking of the weekly test was applied to the second year students. The project manager and two salaried article academic clerks provided the academic support in the form of extra lessons and marking of the tests. At the end of 2006, the 90% pass rate was maintained for the first-year and the second-year students' throughput rate was 75%. The partnership between the University of Johannesburg, SAICA, NISFAS and big business in this innovative programme is yielding astonishing results. The agreement between the students and the stakeholders is that the NISFAS portion of the bursary, in other words R25000, is regarded as a loan to be paid back when the students are employed. However, if the students graduate as chartered accountants only 60% of the loan needs to be repaid; the remaining 40% is considered settled.

6.1. First Recommendation

The researcher obtained all this information through a personal meeting with Mr. Griffioen, the project manager, on the 5 February 2007 at the University of Johannesburg. The results of this meeting encouraged the researcher to consider how similar projects could be implemented by the engineering departments of all South African universities and, in particular, the Chemical and Metallurgical Engineering department at the University of the Witwatersrand.

SAICA's counterpart in the engineering context is the Engineering Council of South Africa. The shortage of engineers in South Africa is well documented (Appendix H). The Minister of Finance tabled the budget in parliament on the 21 February 2007 in which an amount of R2.5 million was allocated to science, technology and engineering in an attempt to redress this problem (The Star Newspaper, 22 February, 2007).

The Engineering Council of South Africa could, as SAICA has done, approach corporate stakeholders with a vested interest in providing South Africa with qualified engineers and meeting their employment equity quotas. This may need to be done through each institute of engineering, such as The Institute of Electrical Engineering or the Institute of Chemical Engineering, so that the companies involved would feel that the money provided would ultimately benefit their particular engineering discipline. In this way bursary funds could be set up for previously disadvantaged students with the potential to become qualified engineers. NISFAS could also be approached as demonstrated by the accounting transformation project.

The idea of finding a separate hostel for the engineering students would address many of the problems identified by previous research on first-year engineering students. Some of the previous problems identified were socio-economic constraints, unstructured study time and no dedicated place of study at home. Those engineering students living in residences, together with students from other faculties, experienced problems of noise distraction and lack of privacy which

negatively affected their ability to cope with the demanding work load (Magangane, 2003; Seabi, 2004; Skuy, 2004).

In the meeting with Mr. Griffioen, it became very clear to the researcher that in order for this type of project to succeed there are two key factors. The first requirement is a project manager who is passionate about making this idea work, as he or she has to liaise with all stakeholders and keep the lines of communication and funding open. He or she is also in charge of all the students, lives with them and spends a lot of time addressing the needs of the students and tutors. The second key factor is that of the tutors. The availability of funding allows the accounting project to pay for additional tutors who can mentor, tutor and mark the students' work whilst giving the students intensive and valuable feedback on their work on a weekly basis, throughout the academic year.

As noted in the Literature review, research conducted by Entwistle McCune and Hounsell (2002) on the UK universities which were involved in the ETL project, found that only one method had been successful. This method was to tutor students over a number of years in a supportive environment. In this manner entrenched study habits were positively changed, thus enhancing academic functioning. Henning's study (2005) found that despite the greater number of tutors available for the Friday tutorial slot, as compared to previous years of the PRME (1002) course, this did not improve academic achievement. The students' perception was that the tutors told them what to do, rather than helped them understand the work. The tutors did not mark tests or give feedback to the students; this was solely the responsibility of the course co-ordinator. There were too many PRME students for him to be able to cope with this on a weekly basis as was implemented in the accounting project. If funding was set aside for experienced tutors to be available in the Chemical and Metallurgical department, implementation of the weekly test and feedback system might be a possible solution in assisting students to bridge the gap between the curriculum and their incoming academic competencies.

6.1.2. Implications for future research

The Faculty of Economic and Financial Sciences, University of the Witwatersrand, also has students who are funded in collaboration with SAICA, by the Thuthuka Bursary programme. However, there is no hostel or extensive tutoring programme provided for these students as has been arranged by the University of Johannesburg. Future research could examine the differences in academic performance between the students of these two programmes, to determine exactly what factors are most beneficial in enhancing the academic performance of students.

The School of Chemical and Metallurgical Engineering at the University of the Witwatersrand could approach the Engineering Council of South Africa, and the Institutes directly related to them, to apply for funding. This funding would enable the School to implement a comprehensive tutor programme for the Chemical and Metallurgy students, similar to that organised by the Accounting Transformation Project at the University of Johannesburg. Research could then be conducted to investigate whether a completely funded tutor programme results in improvement in the academic performance; and hence throughput rate of Chemical and Metallurgy first-year students.

6.2. Second Recommendation

Another possible solution to the curriculum dilemma is the implementation of more lecture time to create equal weighting of a lecture format with active collaboration learning time. At present the PRME (1002) course has one formal lecture per week and the remainder of the time is spent in an active, collaborative peer-learning environment. A paper by Michelle Jones-Wilson (2005), a biochemistry lecturer at a University in Pennsylvania, U.S.A., demonstrated that by combining the lecture format with collaborative group learning, a significant improvement in the understanding by the students resulting in improved academic achievement was achieved. Jones-Wilson used the following format for all the class time with the

students. The students were given detailed outlines of the coursework and comprehensive course notes, which they read in advance. Classes began with a lecture in the first 20 minutes on the material outlined. The students then broke into groups of three to five to work on the assigned exercises. Jones-Wilson circulated and offered any help necessary for the following 25 minutes. The class reconvened for the last 15 minutes, which she handled in a lecture format as she addressed the common problems identified by the students. In the four semesters subsequent to the lecturer's shift to the new format, Jones-Wilson (2005) found that the mean percentile scores of the students increased significantly. The new format also enabled her to cover more material than previously possible in the lecture format alone.

James Lang, an associate professor at Assumption College, U.S.A., argues that "no single teaching technique should constitute the solo pedagogical method in the classroom, that the most effective teachers are those who use multiple approaches: lecturing, group discussion, problem solving sessions, small group work and more" (p. 2, 2006). A comprehensive journal article by Robert De Haan, a professor of educational studies in Atlanta, U.S.A. (2005), outlines the importance of merging the lecture based instructional strategy with the actively engaged learning strategy to optimize levels of understanding, retention and transfer. The lecture-based format is important in providing students with the theory and content knowledge that is central to each discipline. Without this content, students are not able to link the learning of a new idea, or process, with what they already know and they end up learning disconnected facts about the subject. De Haan (2005) comments that the active learning based instructional strategy subsequently helps students in using metacognitive strategies to connect the new information to former knowledge; to plan, monitor and evaluate thinking processes and thus become effective problem solvers by combining both factual knowledge and strategic knowledge of how and when to use specific procedures to solve problems. Thus, both formats are important for learning and understanding.

In conclusion, it may be useful for the PRME (1002) course co-ordinator to review the amount of time spent in each format and restructure the course to be weighted more evenly.

6.2.1. Implications for future research

If the course co-ordinator decides to restructure the PRME (1002) course by allocating equal weighting to the traditional lecture format and the collaborative learning environment, additional research would need to be conducted. The effect on the academic performance of first-year Chemical and Metallurgy students would need to be evaluated. Future research could examine various combinations of the learning formats, to establish the optimal weighting of these environments, which provides both structure as well as active engagement, ensuring academic success for the first-year students.

6.3. Limitations of the study

The sample consisted of 20 students that constituted the whole first-year Metallurgy class of the 2005 PRME (1002) intake. This was done for ethical reasons so that none of the academically weaker students would be excluded from the intervention. Historically, the Metallurgy students have lower entry level matriculation points than their Chemical engineering counterparts, and thus are considered to be weaker academically (Woollacott, personal communication, 2005). However, this meant that the sample size used was very small and this could have had a negative impact on the statistical results. A larger sample may have revealed a significant difference between the mid and end-of-year examination results. The limitation of internal validity exists because the students are used as their own control. The use of a control group may have demonstrated more clearly exactly what impact the cognitive mediation had on the first-year Metallurgy students. It may have controlled for the extraneous variables of maturation and the Hawthorne effect (McBurney, 2001).

6.4. Conclusion

The study aimed to investigate whether an extended cognitive mediated intervention programme of 12 weeks, as opposed to 5 weeks, as conducted in an earlier study (Viviers, 2004), would significantly improve the intellectual functioning and academic performance of the first-year Metallurgy students. The results demonstrated that the intellectual functioning of the students improved significantly as measured by the pre- and post-test scores of the Cognitive Assessment System (CAS). However, no similar significant improvement was seen in the academic performance as measured by the mid-year and end-of-year examination results.

These findings demonstrate that students entering the first-year Metallurgy course are very capable academically as shown by their high entry points (33 and above), as well as by their high scores and significant improvement on the intellectual measurement instrument, viz. the CAS. The findings highlighted that the PRME (1002) course is academically very challenging and difficult for the students to adapt to in their first year. The PRME (1002) course co-ordinator has for the last five years looked at, and researched ways, to bridge the gap between the difficulty of the PRME (1002) course curriculum and the academic competencies of the incoming students as a result of underpreparedness due to their inadequate secondary education. Mediating cognitive functions for only a 12-week period has not shown to have made any real difference to help students with this gap. Perhaps further research could investigate if the cognitive mediation programme happened throughout the academic year, whether the extended period would be a catalyst for the necessary transfer to take place.

Further research could also investigate the issue of transfer in the PRME (1002) course. As indicated by Kotta (2006), the nature of the course is that no two problems are similar and this is what causes difficulties in the area of transfer for the students.

The study shows there is no simple solution to the difficulties faced by the course co-ordinator in order to structure the course to facilitate maximum benefit and academic performance for the students. Mr. Woollacott's efforts are to be commended. Each year the research studies conducted on the PRME (1002) course, have shown valuable findings. This study revealed that mediating cognitive functions for a 12-week period is sufficient time to significantly improve intellectual functioning, but insufficient time to significantly improve academic performance in first-year Metallurgy students.

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APPENDICES

Appendix A Explanation of Adapted cognitive functions from Feuerstein's IE programme

The theoretical framework used in the intervention programme is based on the concept of mediated learning as explicated in detail in the literature review of the study. The Cognitive Research Unit under the leadership of Professor Skuy (2003) adapted and reworked a list of cognitive functions from Feuerstein's Instrumental Enrichment programme (1980). These adapted cognitive functions are divided into three main areas, which correspond to Feuerstein's division of cognitive functions into three phases of the mental act: input, elaboration and output. Input is a phase of behaviour in which information is gathered about the problem to be solved. Professor Skuy and The Cognitive Research Unit (CRU) reworked this and named it the perception functions phase. The elaboration phase became the processing functions phase where information is gathered at the input level and processed. The output phase was renamed the executive function phase. This is where the individual has to emit his response, the product of his elaboration of the data gathered initially. This adaptation by Professor Skuy of Feuerstein's cognitive functions forms Appendix B.

The current research is a follow on of two previous studies supervised by the Cognitive Research Unit. The research study gives detailed information about the findings of the studies. Briefly it was concluded that the area in which the first-year engineering students needed mediation is not in the input or perception functions phase, as the students would need to have mastered these functions in order to register for the PRME course. The two areas in which mediated learning was required was the elaboration or processing functions phase and the output or executive functions phase. Hence this intervention programme has focused on designing the mediated cognitive learning workshops to incorporate these two phases of cognitive functions specifically and their related sub functions. Please refer to the cognitive function information sheet Appendix B for more detailed correlations of the sub functions mediated within each phase.

Appendix B Adapted Cognitive Functions for use in Engineering by Professor Skuy (2003)

IMPORTANT COGNITIVE FUNCTIONS

Adapted from M. Skuy: 'Handbook of Cognitive Functions and Dysfunctions', Cognitive Research Programme, Division of Specialized Education, University of the Witwatersrand, 1991.

FUNCTION CATEGORY	COGNITIVE FUNCTION	SUB FUNCTIONS
PERCEPTION FUNCTIONS	1. Exploration	a) Gathering data
		b) Observing and perceiving
		c) Exploring a situation
		d) Considering more than one source of information
	2. Acquiring Information	a) Acquiring information through language
		b) Acquiring information through graphical, tabular or numerical data
	3. Space & Time Conceptualisation	a) Understanding spatial concepts
		b) Understanding time concepts
	4. Conserving Constancies	a) Conserving unchanging essential properties
PROCESSING FUNCTIONS	5. Task Identification	a) Identifying and defining a task
	6. Identifying Relevance	a) Distinguishing relevant from non-relevant information
	7. Combining Information	a) Making comparisons
		b) Combining relevant information appropriately
		c) Drawing appropriate conclusions
	8. Visualisation	a) Making relevant connections between different items of information
		b) Internalising and generalizing information
		c) Discovering underlying principles
		d) Maintaining visual concepts in different orientations
	9. Being Logical	a) Seeking and checking logical consistency
	10. Planning and Testing	a) Planning and goal-setting
		b) Inferential & hypothetical thinking
		c) Developing & checking a hypothesis or line of argument
	11. Maintaining Continuity	a) Grasping reality meaningfully
		b) Mentally holding & working with several sources of information
EXECUTIVE FUNCTIONS	12. Communication	a) Communicating through language
		b) Communicating through graphical, tabular and numerical data
		c) Formulating clear & accurate responses
	13. Considering Another's Perspective	a) Adapting communication to the audience
	14. Task Execution	a) Working logically and rationally through a task
		b) Producing carefully considered answers
		c) Giving appropriate amounts of attention to each sub-task
	15. Persevering	a) Persevering through difficulties and unfamiliar tasks

Appendix C Letter of Consent

School of Process and Materials Engineering

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Private Bag 3, WITS 2050, South Africa • Telephone + 27 11 71-77510 • Fax +27 11 403-1471

SUBJECT INFORMATION SHEET AND CONSENT FORM

Dear student

For the past two years, the School of Process and Metallurgical Engineering (PRME), has provided an additional academic enrichment programme to support first year engineering students. The purpose of the programme is to provide mediation in selected concepts with which first-year students may have difficulty; and to improve their understanding of these concepts, resulting in improved academic performance. The programme includes participation in a battery of cognitive tests to be used for pre- and post test measurement of the intervention programme.

This programme will take place on Friday afternoons in the allocated time table slots, for the duration of the academic year. Students, who have participated in past programmes of this nature, found the support and mediation to be beneficial.

This programme has a research component, which includes Kim Fairon, a Masters student in Educational Psychology at the University of the Witwatersrand, who in collaboration with Mr. Woollacott will conduct the mediation programme.

While participation in this academic programme is recommended, any student may withdraw at any time.

Yours sincerely

Mr. L. Woollacott
Senior Lecturer
Coordinator of First Year PRME

Kim Fairon
Masters Student

.....

ASSENT FORM

I, _____, will / will not take part in this study, under Conditions stated above and for no other purpose.

Signed: _____ Date: _____

Appendix D Cognitive Intervention Programme (12 Week Outline)

WEEK ONE Processing Functions (Elaboration Phase)

Categorisation

The researcher gave the Metallurgy students non-engineering based exercises to practice the cognitive functions (taken from Appendix B) of:

- Cognitive Function 5 - Task Identification
- Cognitive Function 6 - Identifying Relevance
- Cognitive Function 7 - Combining Information

and all related sub functions (Appendix B).

Discussion and mediation with the class followed the exercises.

The Junior Lecturer concluded the final 20 minutes of the session by transferring this knowledge of cognitive functions into an engineering context using a mediated class engineering exercise (See Appendix C).

WEEK TWO Processing Functions (Elaboration Phase)

Comparisons

The researcher gave the Metallurgy students non-engineering based exercises to practice the cognitive functions (taken from Appendix B) of:

- Cognitive Function 7 - Combining Information
- Cognitive Function 8 - Visualisation

and all related sub functions (Appendix B).

Discussion and mediation with the class followed the exercises.

The Junior Lecturer concluded the final 20 minutes of the session by transferring the new knowledge of cognitive functions into an engineering context using a mediated class engineering exercise.

WEEK THREE Processing Functions (Elaboration Phase)

Analysis and synthesis.

The aim was to mediate the students' knowledge of breaking down information into discrete parts (details) and then synthesizing the data to make sense within a context.

The researcher gave the Metallurgy students non-engineering based exercises to practice the cognitive functions (taken from Appendix B) of:

- Cognitive Function 8 - Visualisation
- Cognitive Function 9 - Being Logical
- Cognitive Function 10 - Planning and Testing

and related sub functions (Appendix B).

The Junior Lecturer concluded the final 20 minutes of the session by transferring this knowledge of cognitive functions into an engineering context using a mediated class engineering exercise.

WEEK FOUR Processing Functions (Elaboration Phase)

Using visual clues- filling in missing information.

The researcher gave the Metallurgy students non-engineering based exercises to practice the cognitive functions (taken from Appendix B) of:

- Cognitive Function 5 - Task Identification
- Cognitive Function 6 - Identifying Relevance

- Cognitive Function 7 - Combining Information
- Cognitive Function 8 - Visualisation
- Cognitive Function 9 - Being Logical
- Cognitive Function 10 - Planning and Testing
- Cognitive Function 11 - Maintaining Continuity

and related sub functions (Appendix B).

The Junior Lecturer concluded the final 20 minutes of the session by transferring this knowledge of cognitive functions into an engineering context using a mediated class engineering exercise.

WEEK FIVE

The Junior Lecturer held a tutorial demonstration using a miniature Jiggly Washer. This is an instrument used to sort different weights and kinds of materials within chemical plants. The exercise visually demonstrates many of the cognitive functions mediated and emphasises their value within the engineering context.

WEEK SIX Processing Functions (Elaboration Phase).

Working Memory Exercise: holding information in working memory while continuing with an unrelated exercise.

The researcher gave the Metallurgy students non-engineering based exercises to practice the cognitive functions (taken from Appendix B) of:

- Cognitive Function 11 - Maintaining Continuity

and the sub functions of:

a) grasping reality meaningfully, and;

b) mentally holding and working with several sources of information.

The Junior Lecturer concluded the final 20 minutes of the session by transferring this knowledge of cognitive functions into an engineering context using a mediated class engineering exercise.

WEEK SEVEN Executive Functions (Output Phase)

Describing and interpreting information - important differences.

The researcher gave the Metallurgy students non-engineering based exercises to practice the cognitive functions (taken from Appendix B) of:

- Cognitive Function 12 - Communication
- Cognitive Function 14 - Maintaining Continuity

The Junior Lecturer concluded the final 20 minutes of the session by transferring this knowledge of cognitive functions into an engineering context using a mediated class engineering exercise.

WEEK EIGHT Executive Functions (Output Phase)

Finding and choosing the best solution path

The researcher gave the Metallurgy students non-engineering based exercises to practice the cognitive functions (taken from Appendix B) of:

- Cognitive Function 5 - Task Identification
- Cognitive Function 6 - Identifying Relevance
- Cognitive Function 7 - Combining Information
- Cognitive Function 8 - Visualisation
- Cognitive Function 9 - Being Logical
- Cognitive Function 10 - Planning and Testing
- Cognitive Function 11 - Maintaining Continuity

And executive functions:

- Cognitive Function 12 - Communication
- Cognitive Function 13 – Considering Another's Perspective
- Cognitive Function 14 - Maintaining Continuity

and all related sub functions (Appendix B).

The Junior Lecturer concluded the final 20 minutes of the session by transferring this knowledge of cognitive functions into an engineering context using a mediated class engineering exercise.

WEEK NINE Processing and Executive Functions (Elaboration and Output Phase.)

Analysing cognitive strategies

The researcher gave the Metallurgy students non-engineering based exercises to practice the cognitive functions (taken from Appendix B) of:

- Cognitive Functions 5, 6, 7, 8, 9, 10 and 11

And executive functions:

- Cognitive Function 12 - Communication
- Cognitive Function 13 – Considering Another's Perspective
- Cognitive Function 14 - Maintaining Continuity
- Cognitive Function 15 - Persevering

and all related sub functions (Appendix B).

The Junior Lecturer concluded the final 20 minutes of the session by transferring this knowledge of cognitive functions into an engineering context using a mediated class engineering exercise.

WEEK TEN **Processing and Executive Functions (Elaboration and Output Phase)**

Analysing and Identifying Cognitive Strategies.

The researcher gave the Metallurgy students non-engineering based exercises to practice the cognitive functions (taken from Appendix B) of:

- Cognitive Functions 5, 6, 7, 8, 9, 10 and 11

and executive functions:

- Cognitive Function 12 - Communication
- Cognitive Function 13 – Considering Another's Perspective
- Cognitive Function 14 - Maintaining Continuity
- Cognitive Function 15 - Persevering

and all related sub functions (Appendix B).

The Junior Lecturer concluded the final 20 minutes of the session by transferring this knowledge of cognitive functions into an engineering context using a mediated class engineering exercise.

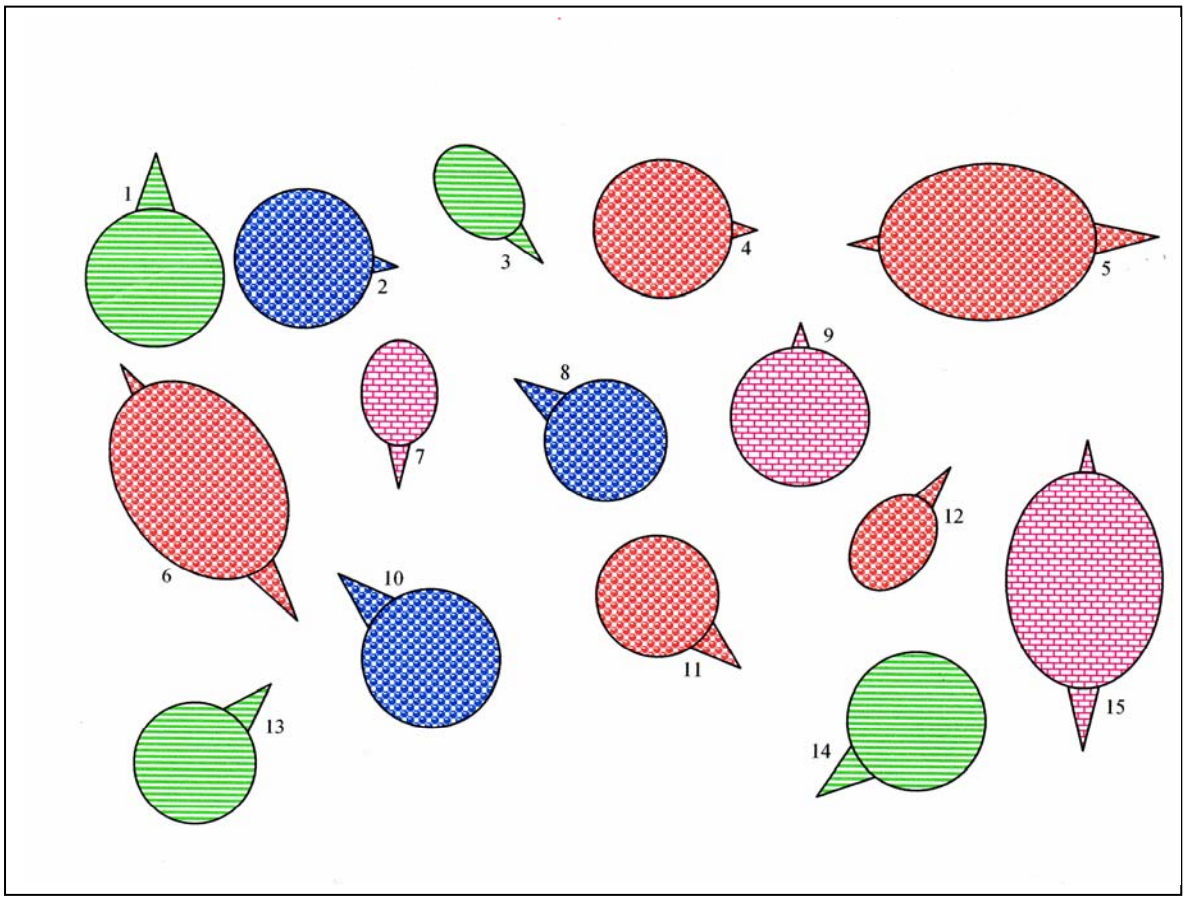
WEEKS 11 AND 12

Summary and evaluation of intervention programme: mediated any cognitive functions within engineering context that were still unclear.

Appendix E Cognitive Intervention Programme for Friday 29 July 2005

Cognitive function mediated - categorisation

The researcher handed out the bubble diagrams to all 20 Metallurgy students. The students were asked to spend ten minutes categorising the bubbles under different headings. After 10 minutes the class had a discussion with the researcher. The different ways of categorisation were discussed. The bubbles could be grouped together under headings such a size, shape, colour, orientation and fill texture. The researcher and Metallurgy class discussed the importance of comparisons and similarities. The Researcher asked the students to think metacognitively about how this could help them in the engineering context. The concept of concentration was the PRME (1002) topic for that week. The researcher and the class discussed this briefly.



Then the Junior Lecturer handed out the prepared exercise for the week. The students completed the exercise. The answers were discussed as a class. From this exercise it became clear how placing different measures of concentration in categories, helped the students understand the concept of concentration.

Met Intervention – Friday 29/07 PRME 1002

Instructions

1. List the categories used to organise the information presented below.
2. What concept is being expressed in this exercise?

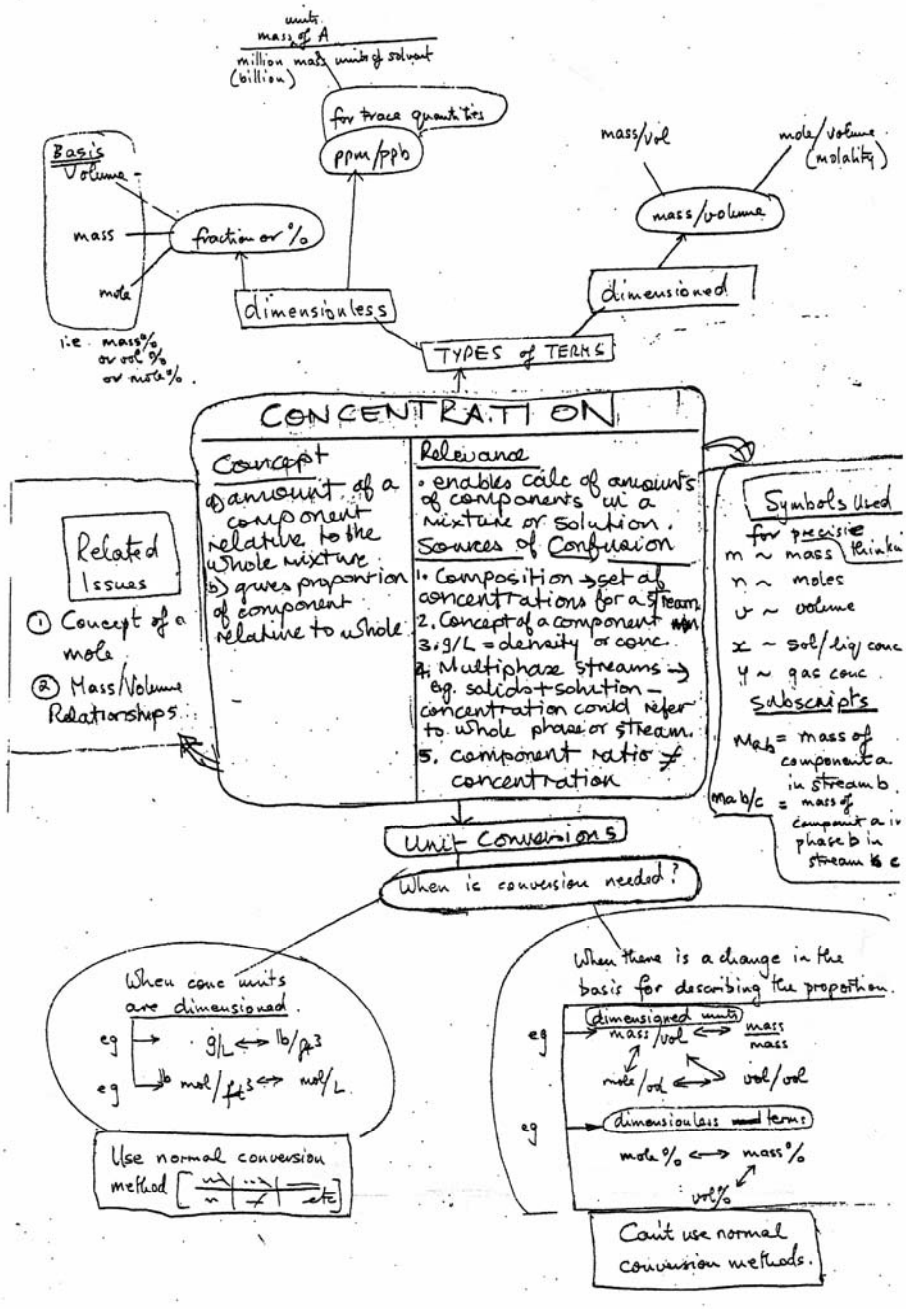
ppm	mole% ↔mass%	mass/vol
mixture	vol%	mass/vol ↔mass/mass
amount of substance relative to whole	multicomponent stream	ppb
mass%	g/l↔lb/ft^3 mol/ft^3 ↔mol/l	proportion of component relative to
solution	mole/volume	mole%

The Friday tutorial focused on the concept of concentration.

3Q1eF: FRIDAY TUT SESSION

The format for afternoon Tutorial sessions will be slightly different for the rest of the year. The work to be done this Friday will be as follows:-

1. **Visualization and Interpretation**
   Interpret the Ni – Co flowsheet as best you. Without worrying about neatness etc, write down your interpretations, questions and diagrams. Further instructions will follow after a class discussion. You will be handing in this work.
2. **Concept Map**
   To develop your analytical and 'trouble-shooting' skills, study the Concept Map on Concentration. Then do the following tasks. (Note: You will be handing in this work.)
   a) List the categories used to organize the information relating to the concept of concentration.
   b) Next to each item in your list indicate the degree of importance and/or generality.
   c) How is a concept map like this useful to you?
3. **Temperature Tut and Tutorial 4.**
   Work through this after you have completed the other work



Appendix F – Statgraphics Example

StatAdvisor (www.statgraphics.com)

Paired Samples - End of Year Exams & Mid Year Exam
Data variable: End of Year Exams-Mid Year Exam
20 values ranging from -8.0 to 6.0

The StatAdvisor
This procedure is designed to test for significant differences between two data samples where the data were collected as pairs. It will calculate various statistics and graphs for the differences between the paired data. Also included in the procedure are tests designed to determine whether the mean difference is equal to zero. Use the Tabular Options and Graphical Options buttons on the analysis toolbar to access these different procedures.

Summary Statistics for End of Year Exams-Mid Year Exam

Count	20
Average	0.5
Standard deviation	4.199
Coeff. of variation	839.799%
Minimum	-8.0
Maximum	6.0
Range	14.0
Stnd. skewness	-1.07728
Stnd. kurtosis	-0.662753

The StatAdvisor
This table shows summary statistics for End of Year Exams-Mid Year Exam. It includes measures of central tendency, measures of variability, and measures of shape. Of particular interest here are the standardized skewness and standardized kurtosis, which can be used to determine whether the sample comes from a normal distribution. Values of these statistics outside the range of -2 to +2 indicate significant departures from normality, which would tend to invalidate any statistical test regarding the standard deviation. In this case, the standardized skewness value is within the range expected for data from a normal distribution. The standardized kurtosis value is within the range expected for data from a normal distribution.

Frequency Tabulation for End of Year Exams-Mid Year Exam

Class	*Lower Limit*	*Upper Limit*	*Midpoint*	*Frequency*	*Relative Frequency*	*Cumulative Frequency*	*Cum. Rel. Frequency*
	at or below	-9.0		0	0.0000	0	0.0000
1	-9.0	-6.33333	-7.66667	1	0.0500	1	0.0500
2	-6.33333	-3.66667	-5.0	3	0.1500	4	0.2000
3	-3.66667	-1.0	-2.33333	3	0.1500	7	0.3500
4	-1.0	1.66667	0.333333	4	0.2000	11	0.5500
5	1.66667	4.33333	3.0	4	0.2000	15	0.7500
6	4.33333	7.0	5.66667	5	0.2500	20	1.0000
	above	7.0		0	0.0000	20	1.0000

Mean = 0.5 Standard deviation = 4.199

The StatAdvisor
This option performs a frequency tabulation by dividing the range of End of Year Exams-Mid Year Exam into equal width intervals and counting the number of data values in each interval. The frequencies show the number of data values in each interval, while the relative frequencies show the proportions in each interval. You can change the definition of the intervals by pressing the alternate mouse button and selecting Pane Options. You can see the results of the tabulation graphically by selecting Frequency Histogram from the list of Graphical Options.

Stem-and-Leaf Display for End: unit = 1.0 1|2 represents 12.0

```
  1     -0|8
  3     -0|66
  4     -0|4
  7     -0|322
  7     -0|
(4)      0|1111
  9      0|2333
  5      0|5555
  1      0|6
```

The StatAdvisor
This display shows a frequency tabulation for End of Year Exams-Mid Year Exam. The range of the data has been divided into 9 intervals (called stems), each represented by a row of the table. The stems are labeled using one or more leading digits for the data values falling within that interval On each row, the individual data values are represented by a digit (called a leaf) to the right of the vertical line. This results in a histogram of the data from which you can recover at least two significant digits for each data value. If there are any points lying far away from most of the others (called outside points), they are placed on separate high and low stems. In this case, there are no outside points. Outside points are illustrated graphically on the box-and-whisker plot, which you can access via the list of Graphical Options. The leftmost column of numbers are depths, whicl give cumulative counts from the top and bottom of the table, stopping at the row which contains the median.

Confidence Intervals for End of Year Exams-Mid Year Exam
95.0% confidence interval for mean: 0.5 +/- 1.9652 [-1.4652,2.4652]
95.0% confidence interval for standard deviation: [3.1933,6.13294]

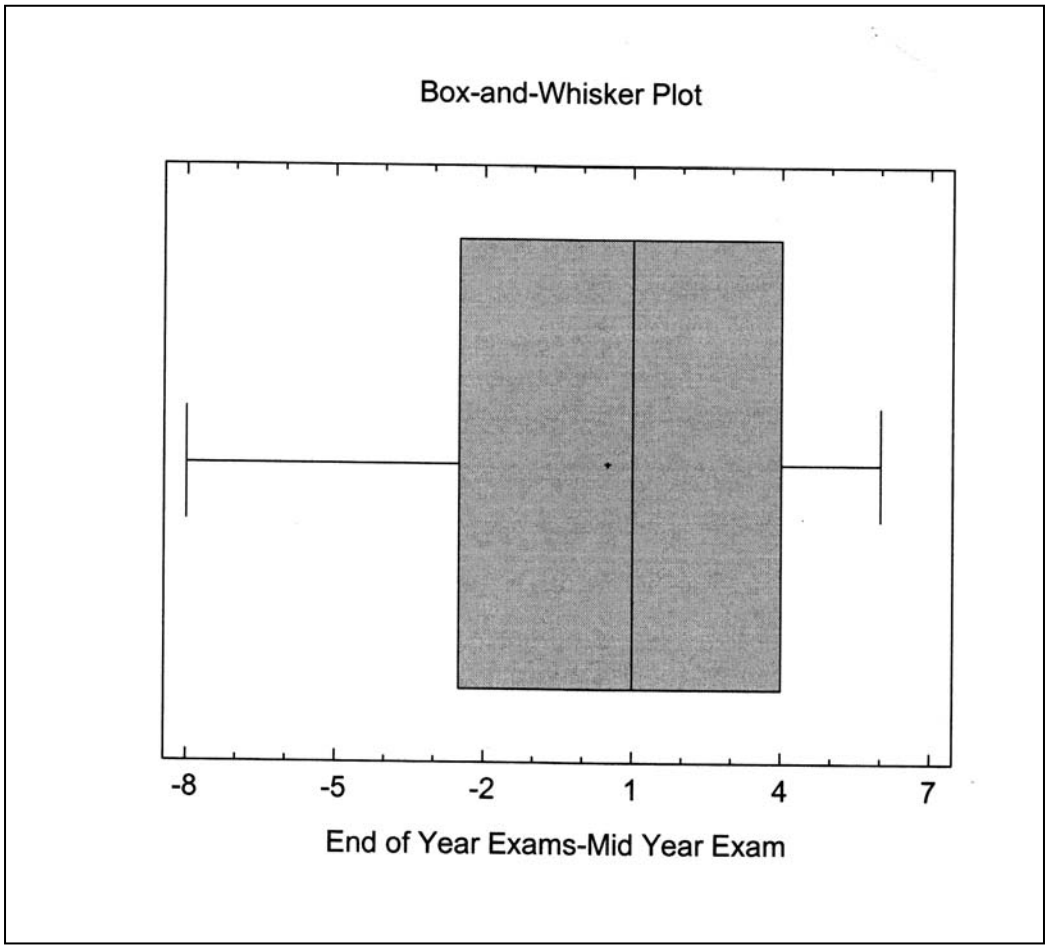
The StatAdvisor
This pane displays 95.0% confidence intervals for the mean and standard deviation of End of Year Exams-Mid Year Exam. The classical interpretation of these intervals is that, in repeated sampling, these intervals will contain the true mean or standard deviation of the population from which the data come 95.0% of the time. In practical terms, we can state with 95.0% confidence that the true mean End of Year Exams-Mid Year Exam is somewhere between -1.4652 and 2.4652, while the true standard deviation is somewhere between 3.1933 and 6.13294.

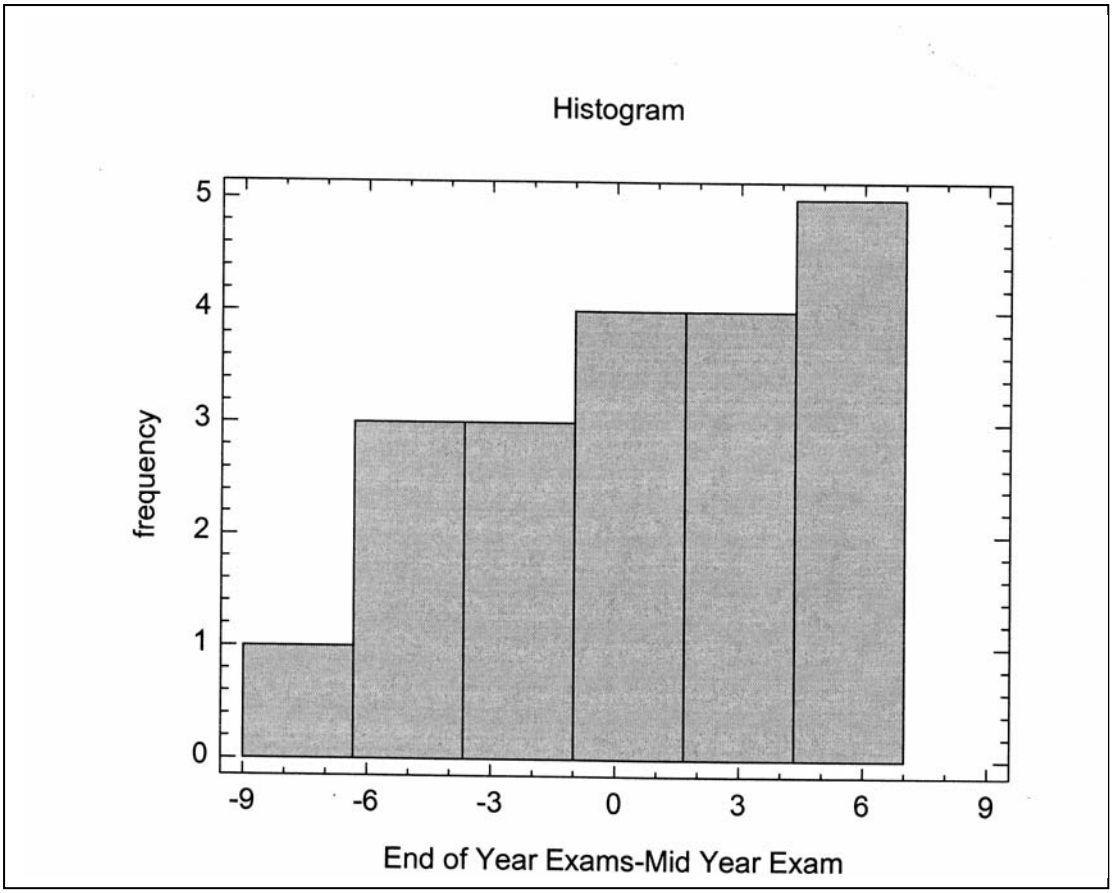
Both intervals assume that the population from which the sample comes can be represented by a normal distribution. While the confidence interval for the mean is quite robust and not very sensitive to violations of this assumption, the confidence interval for the standard deviation is quite sensitive. If the data do not come from a normal distribution, the interval for the standard deviation may be incorrect. To check whether the data come from a normal distribution, select Summary Statistics from the list of Tabular Options, or choose Normal Probability Plot from the list of Graphical Options.

Percentiles for End of Year Exams-Mid Year Exam

	Percentiles
1.0%	-8.0
5.0%	-7.0
10.0%	-6.0
25.0%	-2.5
50.0%	1.0
75.0%	4.0
90.0%	5.0
95.0%	5.5
99.0%	6.0

The StatAdvisor
This pane shows sample percentiles for End of Year Exams-Mid Year Exam. The percentiles are values below which specific percentages of the data are found. You can see the percentiles graphically by selecting Quantile Plot from the list of Graphical Options.

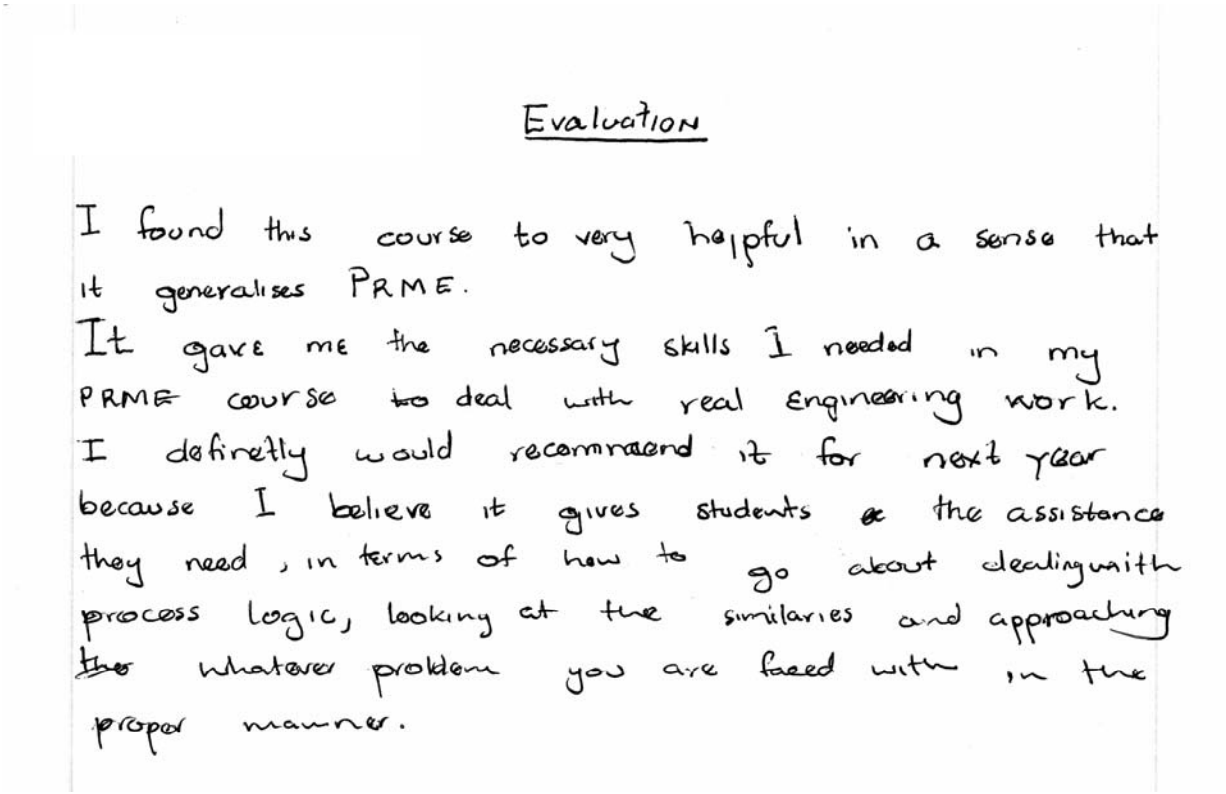

Box-and-Whisker Plot
-8
-5
-2
1
4
7
End of Year Exams-Mid Year Exam


Histogram
frequency
0
1
2
3
4
5
-9
-6
-3
0
3
6
9
End of Year Exams-Mid Year Exam

Appendix G – A Selection of Student Evaluations of the Cognitive Mediated Programme

Student A

I found this course is to be very helpful in a sense that it generalises PRME. It gave me the necessary skills I needed in my PRME course to deal with real engineering work. I definitely would recommend it for next year because I believe it gives students the assistance they need, in terms of heart to go about dealing with process logic, looking at the similaries (sic) and approaching whatever problem you are faced with in of the proper manner.

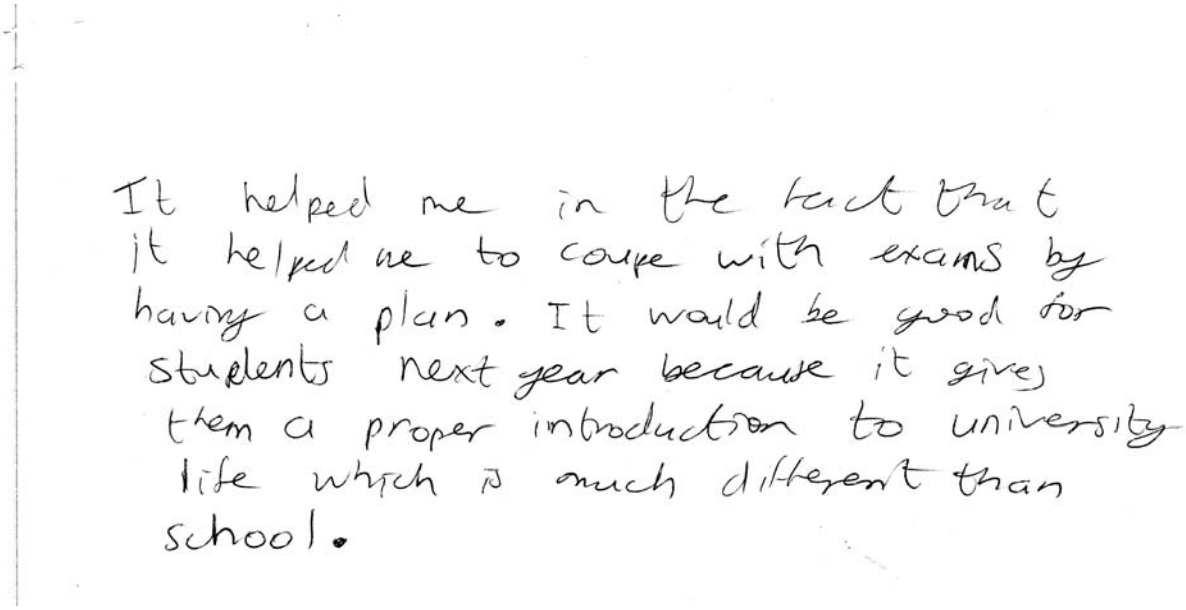


Evaluation

I found this course to very helpful in a sense that it generalises PRME.
It gave me the necessary skills I needed in my PRME course to deal with real Engineering work.
I definetly would recommend it for next year because I believe it gives students the assistance they need, in terms of how to go about dealing with process logic, looking at the similaries and approaching whatever problem you are faced with, in the proper manner.

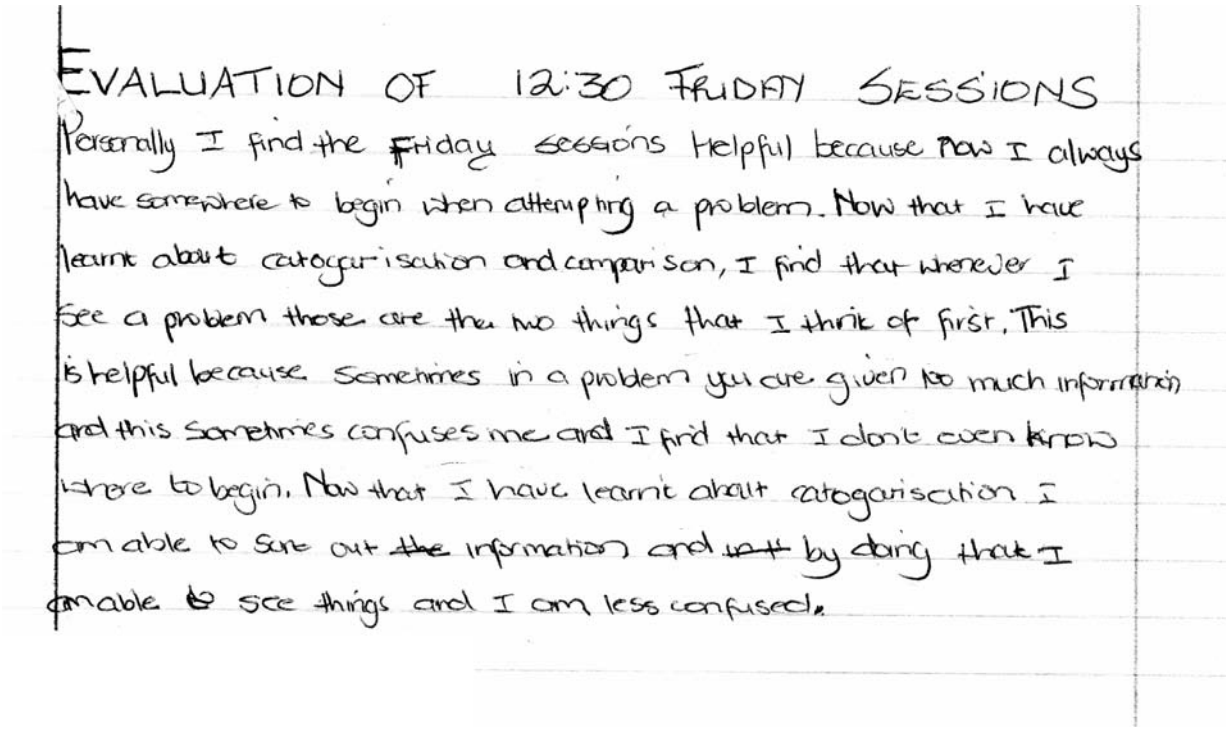
Student B

It helps me in the fact that it helped me to cope with exams by having a plan. It would be good for students next year because it gives them a proper introduction to university life which is much different from school.



Student C

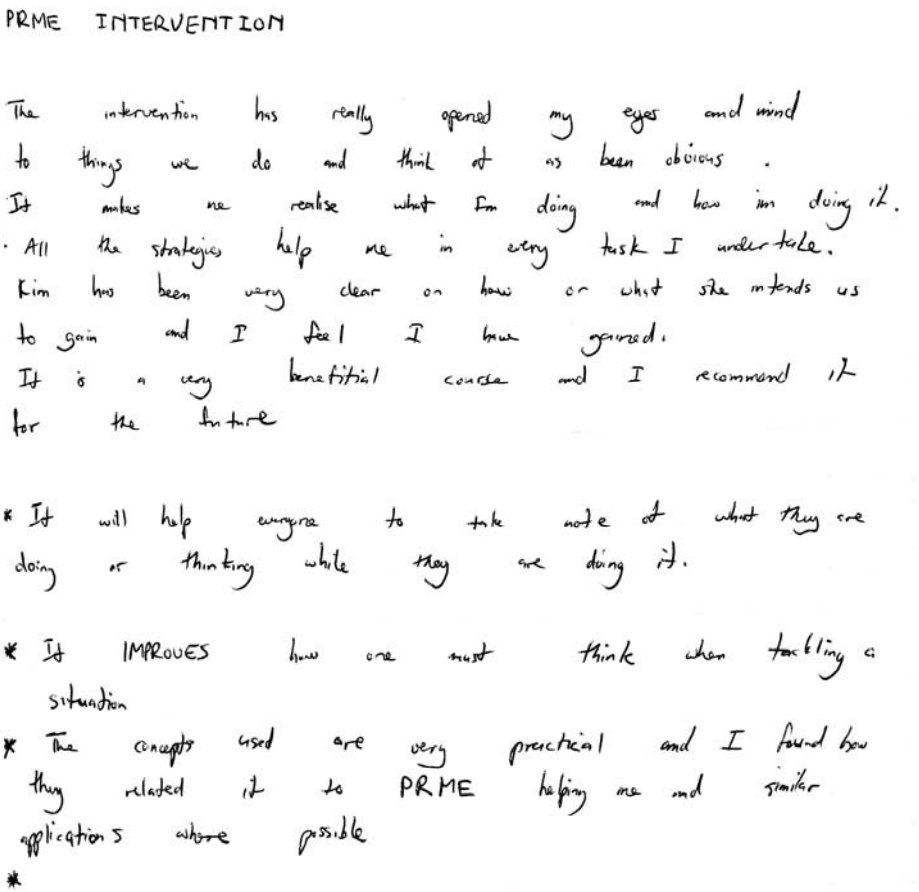
Personally I find the Friday sessions helpful because now I always have somewhere to begin when attempting a problem. Now that I have learnt about categorisation and comparison, I find that whenever I see a problem those are the two things that I think of first. This is helpful because sometimes in a problem you are given too much information and this sometimes confuses me and I find that I don't even know where to begin. Now that I have learnt about categorisation I am able to sort out information and by doing that I am able to see things and I am less confused.


EVALUATION OF 12:30 FRIDAY SESSIONS

Personally I find the ~~F~~Friday sessions helpful because now I always have somewhere to begin when attempting a problem. Now that I have learnt about categorisation and comparison, I find that whenever I see a problem those are the two things that I think of first. This is helpful because sometimes in a problem you are given too much information and this sometimes confuses me and I find that I don't even know where to begin. Now that I have learnt about categorisation I am able to sort out ~~the~~ information and ~~it~~ by doing that I am able to see things and I am less confused.

Student D

- The intervention has really opened my eyes and mind to things we do and think at as being the obvious (sic).
- It makes me realise what I am doing and how I am doing it.
- All the strategies helped me in every task I undertake.
- Kim has been very clear on how or what she intends us to gain and I feel I have gained.
- It is a very beneficial course and I recommend it for the future.
- It will help everyone to take note of what they are doing or thinking while they were doing it.
- It improves how one must think when tackling a situation.
- The concepts used are very practical and I found how are they related it to PRME helping me and similar applications where possible.



PRME INTERVENTION

The intervention has really opened my eyes and mind to things we do and think at as been obvious.
It makes me realise what I'm doing and how im doing it.
All the strategies help me in every task I undertake.
Kim has been very clear on how or what she intends us to gain and I feel I have gained.
It is a very benefitial course and I recommend it for the future

* It will help everyone to take note of what they are doing or thinking while they are doing it.

* It IMPROVES how one must think when tackling a situation

* The concepts used are very practical and I found how they related it to PRME helping me and similar applications where possible

*

Appendix H – Newspaper Article



Plan to produce 1000 more engineers a year

SOUTH Africa's higher education institutions have undertaken to increase the number of engineering graduates by an extra 1 000 a year.

The initiative is part of the government's plan to address the country's mounting demand for scarce skills.

But the plan could face serious setbacks because of the poor quality of first-year students enrolling for engineering degrees.

This is according to a confidential government document in which tertiary institutions expressed serious concern over "the quality of incoming students".

Institutions said although pupils' matric symbols might be high, "they do not represent real learning".

The criticism levelled by tertiary institutions against the schooling system includes:

- Comments like "we can't believe they [pupils] have completed school as their skills are very weak";
- Claims that students don't have good habits and don't prepare for classes; and
- The poor attitude of students.

Wits University said even where students had distinctions in matric, it was not a reliable indicator.

The document also revealed that tests done by Tshwane University of Technology showed students with distinctions in maths failed to pass first-year maths.

Academics cited "underprepared" students as one of the main reasons for the high dropout rate.

Figures released by Education Minister Naledi Pandor showed that out of an initial enrolment of 49 765 first-time undergraduate students in all disciplines in 2001, 17 417 dropped out by the end of the third year and only 18 911 graduated in the fourth year.

Professor Duma Malaza, chief executive of Higher Education South Africa, confirmed that deans of engineering faculties agreed at a meeting this week to increase the number of engineering graduates.

According to statistics from the Engineering Council of South Africa, universities produced 8 903 engineering graduates between 1998 and 2004, with 1 775 of them being African.

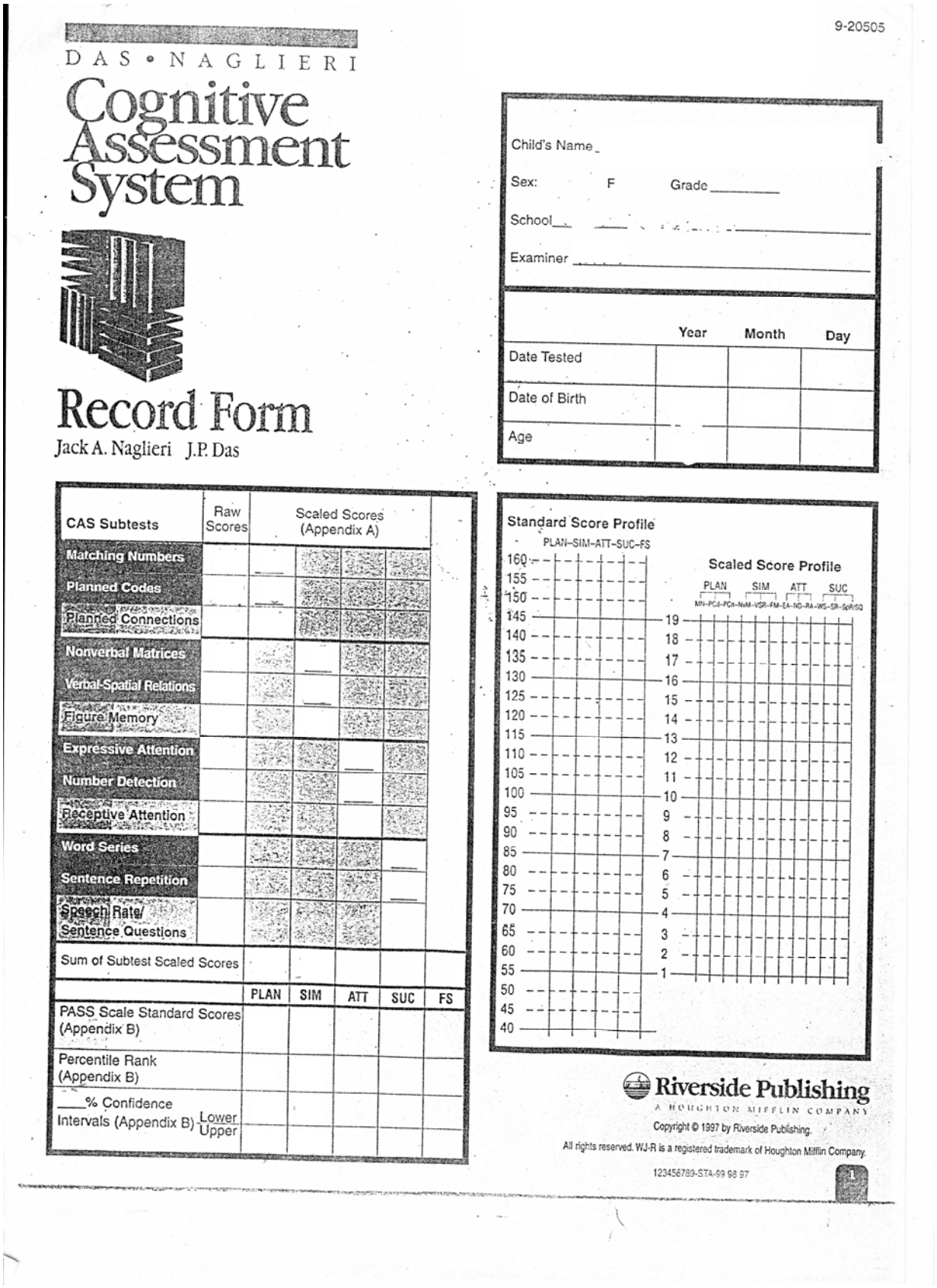
The University of Pretoria — which produces almost a third of the country's engineers — proposed doubling its number of engineering graduates from 524 to 1 055.

The University of KwaZulu-Natal, which produced 312 graduates last year, plans to increase this to 500. Wits University proposed increasing its output from 390 to 600, while Stellenbosch University aimed at increasing its number from 263 to 363.

Pandor recently allocated R48-million to universities to increase the number of engineering graduates. — *Prega Govender*

The Sunday Times Newspaper
24 September 2006

Appendix I – The Record Sheet of the Cognitive Assessment System



9-20505

DAS • NAGLIERI

Cognitive Assessment System

Record Form

Jack A. Naglieri J.P. Das

Child's Name

Sex: F Grade

School

Examiner

	Year	Month	Day
Date Tested			
Date of Birth			
Age			

CAS Subtests	Raw Scores	Scaled Scores (Appendix A)			
Matching Numbers					
Planned Codes					
Planned Connections					
Nonverbal Matrices					
Verbal-Spatial Relations					
Figure Memory					
Expressive Attention					
Number Detection					
Receptive Attention					
Word Series					
Sentence Repetition					
Speech Rate/ Sentence Questions					
Sum of Subtest Scaled Scores					

	PLAN	SIM	ATT	SUC	FS
PASS Scale Standard Scores (Appendix B)					
Percentile Rank (Appendix B)					
___% Confidence Intervals (Appendix B) Lower					
Upper					

Standard Score Profile

PLAN–SIM–ATT–SUC–FS

160 155 150 145 140 135 130 125 120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45 40

Scaled Score Profile

PLAN SIM ATT SUC

MN–PCd–PCn–NvM–VSR–FM–EA–ND–RA–WS–SR–SpR/SQ

19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

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12345678-STA-99 98 97

1

Matching Numbers

Materials Administration and Scoring Manual, pages 13-18
Response Book for Ages 5–7, pages 1-3
Response Book for Ages 8–17, pages 1-4
Red pencil
Stopwatch

Administer Ages 5–7: Demonstration, Samples A & B, Items 1-2
Ages 8–17: Demonstration, Samples A & B, Items 2-4

Time Limits See below

Record Time in seconds
Number correct
Strategy Assessment

	Item	Time Limit	Time in seconds	Accuracy Score (Number Correct)	Ratio Score (see pp. 14-16) Ages 5–7	Ratio Score (see pp. 14-16) Ages 8–17
All Ages	Demo					
	Sample A					
	Sample B					
5–7 Years	1.	150"(2:30)				
					+	
8–17 Years	2.	150"(2:30)				
5–7 Stop					+	
	3.	150"(2:30)				
					+	
	4.	180"(3:00)				
8–17 Stop					=	=
	Raw Score					
					Sum of ratio scores, Items 1-2	Sum of ratio scores, Items 2-4

Strategy Assessment Checklist

Obs	Rep	Description of Strategy
		1. Looked at first, then last, then middle number
		2. Looked at first then last digit of each number
		3. Looked at first two digits of each number
		4. Looked at last number, then first
		5. Looked at first digit of each number
		6. Put finger on number and tried to find its match
		7. Matched first, then second number; continued row until match found
		8. Verbalized the numbers
		9. Looked at the last digits to find a match
		10. Scanned row (either direction) for match
		11. No strategy

Other:
Observed _____
Reported _____

Planned Codes

Materials Administration and Scoring Manual, pages 19-23
Response Book for Ages 5–7, pages 4-7
Response Book for Ages 8–17, pages 5-8
Red pencil
Stopwatch

Administer All samples and items

Time Limits See below

Record Time in seconds
Number correct
Strategy Assessment

	Item	Time Limit Ages 5–7	Time Limit Ages 8–17	Time in seconds	Accuracy Score (Number Correct)	Ratio Score (see pp. 14-16)
All Ages	Sample A					
	1.	120"(2:00)	60"(1:00)			
	Sample B					+
	2.	120"(2:00)	60"(1:00)			
						=
	Raw Score					

Strategy Assessment Checklist

Item 1

Obs	Rep	Description of Strategy
		1. Coded entire row, ABCDABCD, left to right, top to bottom
		2. Said codes to self out loud
		3. Coded half of row, ABCD, left to right, top to bottom, then repeat
		4. Coded As in first column, Bs in second column, etc.
		5. Coded right to left or bottom to top
		6. Coded both A columns, then both B columns, etc.
		7. Looked at codes already completed rather than key
		8. Coded neatly and slowly
		9. No strategy

Other:
Observed _____
Reported _____

Item 2

Obs	Rep	Description of Strategy
		1. Coded entire row, left to right, top to bottom
		2. Coded right to left from bottom to top
		3. Said codes to self out loud
		4. Coded ABCD diagonally from left to right, top to bottom
		5. Coded As on diagonal, then Bs, etc.
		6. Coded all As on diagonal, then all Bs, etc.
		7. Coded diagonally in pairs (AB, CD) from left to right, top to bottom
		8. Coded neatly and slowly
		9. Began coding as though pattern was the same as PCd 1
		10. No strategy

Other:
Observed _____
Reported _____

Planned Connections

Materials Administration and Scoring Manual, pages 24-29
Response Book for Ages 5–7, pages 8-14
Response Book for Ages 8–17, pages 9-17
Red pencil, Stopwatch

Administer Ages 5–7: Demonstration, Sample A, Items 1-5
Ages 8–17: Sample A, Items 4-6,
Sample B, Items 7-8

Time Limits See below

Record Time in seconds
Strategy Assessment

	Item	Time Limit	Time in seconds Ages 5–7	Time in seconds Ages 8–17
5–7 Years	Demonstration			
8–17 Years	Sample A			
	1.	60" (1:00)		
	2.	60" (1:00)		
	3.	90" (1:30)		
	4.	90" (1:30)		
	5.	150" (2:30)		
5–7 Stop	6.	150" (2:30)		
	Sample B			
	7.	150" (2:30)		
	8.	180" (3:00)		
8–17 Stop				
	Raw Score			
			Sum of Items 1-5, Total Seconds	Sum of Items 4-8, Total Seconds

Strategy Assessment Checklist

Obs	Rep	Description of Strategy
		1. Scanned page for next number or letter
		2. Remembered last number or letter
		3. Lifted hand off the page to see better
		4. Looked back at last number or letter
		5. Repeated alphabet/number series out loud
		6. Repeated alphabet/number series to self
		7. No strategy

Other:
Observed _____
Reported _____

Nonverbal Matrices

Materials Administration and Scoring Manual, pages 31-34
Stimulus Book, pages 1-67

Start Ages 5–7: Sample, Item 1
Ages 8–17: Sample, Item 7

Discontinue After 4 consecutive items failed

Drop Back If a child ages 8–17 fails Item 7, then give Item 1 (using the directions for ages 5–7) and administer forward until the discontinue rule has been met.

Record Child's response

Score Pass = 1, Fail = 0

	Item	Correct Response	Child's Response	Score 1 or 0
All Ages	Sample	1		
5–7 Years	1.	4		
	2.	2		
	3.	3		
	4.	5		
	5.	5		
	6.	3		
8–17 Years	7.	1		
	8.	4		
	9.	2		
	10.	4		
	11.	5		
	12.	2		
	13.	4		
	14.	2		
	15.	1		
	16.	3		
	17.	2		
	18.	3		
	19.	5		
	20.	4		
	21.	4		
	22.	2		
	23.	6		
	24.	2		
	25.	3		
	26.	6		
	27.	3		
	28.	1		
	29.	1		
	30.	2		
	31.	5		
	32.	6		
	33.	4		
	Raw Score			

Sum all item scores, giving credit (1) for each item not administered below the starting point

Verbal-Spatial Relations

Materials Administration and Scoring Manual, pages 35-40
Stimulus Book, pages 69-123
Stopwatch

Start Ages 5–7: Sample, Item 1
Ages 8–17: Sample, Item 7

Discontinue After 4 consecutive items failed

Drop Back If a child ages 8–17 fails Item 7, then give Item 1 (using the directions for ages 5–7) and administer forward until the discontinue rule has been met.

Time Limit 30 seconds per item

Record Child's response

Score Pass = 1, Fail = 0

	Item	Correct Response	Child's Response	Score 1 or 0
All Ages	Sample	1		
5–7 Years	1.	3		
	2.	2		
	3.	4		
	4.	5		
	5.	6		
	6.	2		
8–17 Years	7.	1		
	8.	4		
	9.	3		
	10.	5		
	11.	1		
	12.	3		
	13.	2		
	14.	6		
	15.	2		
	16.	5		
	17.	3		
	18.	4		
	19.	5		
	20.	2		
	21.	1		
	22.	4		
	23.	6		
	24.	5		
	25.	4		
	26.	1		
	27.	6		

Raw Score

Sum all item scores, giving credit (1) for each item not administered below the starting point

Figure Memory

Materials Administration and Scoring Manual, pages 41-50
Stimulus Book, pages 125-237
Figure Memory Response Book, pages 1-57
Red pencil
Stopwatch

Start Ages 5–7: Demonstration, Sample, Item 1
Ages 8–17: Demonstration, Sample, Item 3

Discontinue After 4 consecutive items failed

Drop Back If a child ages 8–17 fails Item 3, then give Item 1 (using the directions for ages 5–7) and administer forward until the discontinue rule has been met.

Time Limit Expose each stimulus for 5 seconds

Score Pass = 1, Fail = 0

	Item	Score 1 or 0
All Ages	Demonstration	
	Sample	
5–7 Years	1.	
	2.	
8–17 Years	3.	
	4.	
	5.	
	6.	
	7.	
	8.	
	9.	
	10.	
	11.	
	12.	
	13.	
	14.	
	15.	
	16.	
	17.	
	18.	
	19.	
	20.	
	21.	
	22.	
	23.	
	24.	
	25.	
	26.	
	27.	

Raw Score

Sum all item scores, giving credit (1) for each item not administered below the starting point